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APPLIED
MECHANICAL DRAWING

FOR FIRST AND SECOND YEAR CLASSES IN HIGH SCHOOLS: TECHNICAL, TRADE AND VOCATIONAL COURSES, AND EVENING SCHOOLS

BY

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FORMERLY ASSISTANT PRINCIPAL: IN CHARGE OF SHOP WORK AND MECHANICAL DRAWING, CLEVELAND TECHNICAL HIGH SCHOOL
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PREFACE

In planning this course in Applied Mechanical Drawing for pupils in the first and second years of high school, the main purpose has been to establish, wherever possible, a close relation between mechanical drawing, mathematics and shopwork, omitting the usual abstract problems which have no direct application to either subject. Almost without exception, each problem demands some mathematical calculation before the pupil can proceed with the drawing.

Our experience leads us to believe that it is the better plan to present a minimum amount of explanatory text in connection with a completed drawing of a typical problem coming under each topic in the course. This enables the pupil to readily comprehend and easily understand the requirements of the ensuing problems which are given in text form. Wherever necessary these problems are accompanied by freehand perspective sketches suggesting the object which is to be represented by the mechanical drawing.

The problems in design for shop drawings of woodturning and simple pieces of furniture offer an excellent opportunity to relate constructive design in the drawing room to the practical work of the shop courses. In this connection it has been found more practical and productive of better results to present a number of suggestive outlines which aid the pupil to design and draw the particular piece that he plans to construct in the shops.

Facility in design ought not to be considered the chief aim in working out these problems. The important thing lies in the development of fundamental ideas in regard to the relation between work at the drawing board and work in the shop; the awakening of the sense of proportion; suggesting the fitness of form, size and materials to the requirements of the special problem under consideration. That this relation between drawing room and workshop may be firmly established and the work successfully accomplished, has been practically demonstrated during the past two years in the school with which the authors are connected. We have found that the satisfaction and pride that the pupil has in successfully designing and executing a piece of work that is largely of his own creation, stimulates him to better work all through his course in the school.

To adapt the course to classes in schools which do not offer manual training it is necessary only to leave out that part relating directly to woodworking drawing.

CLEVELAND, FEBRUARY, 1911.

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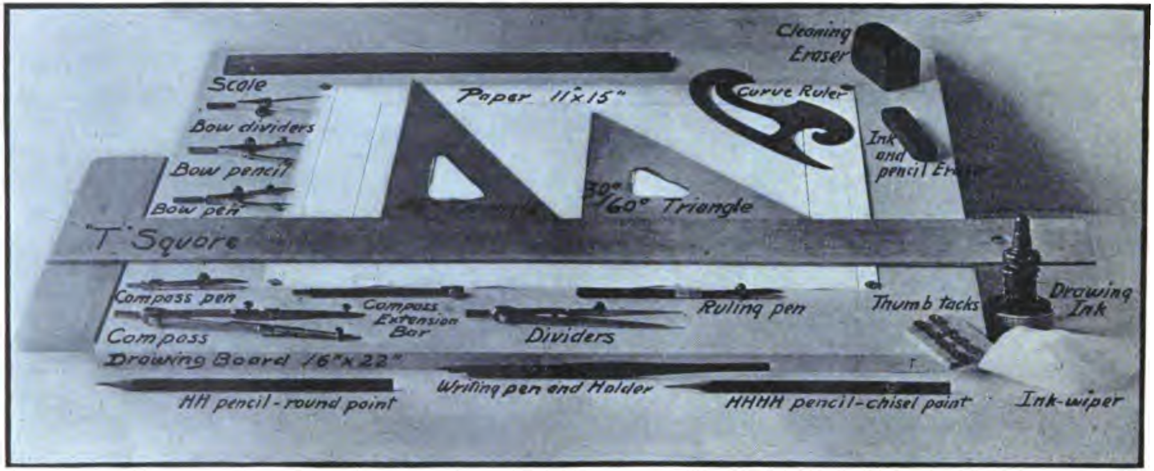


PLATE I. MECHANICAL DRAWING EQUIPMENT

—: APPLIED :—

MECHANICAL DRAWING

BOOK ONE

INTRODUCTION: THE DRAWING INSTRUMENTS

Mechanical Drawing is used by those familiar with its methods and conventions, as a means of expression through a medium of lines, drawn on paper or other suitable material, so arranged that they will convey a clear, definite conception of any mechanical and architectural construction already existing, or that also which only exists in the mind of the inventor, architect, engineer or designer. To such men, drawing, and especially mechanical drawing, is essential, for through its use they are thus enabled to make graphic representation of their inventive ideas, recording them in a way that makes them of permanent value. From the fact that it is necessary in drawings made for such purposes, to obtain a high degree of accuracy in representation, much, if not all, of this kind of drawing must be executed by the aid of instruments especially designed for the purpose; hence the term "*Mechanical Drawing*" is applied to such drawing. The instruments required, which are commonly used in Mechanical Drawing, are illustrated in Plate I and the following brief description explains their use in the order in which they are employed in making the drawing plates.

The T Square. The head of the T square should be held firmly against the left-hand edge of the drawing board and used by running it up or down along this edge. The upper edge of the blade is the working edge, either for drawing all horizontal lines or for the triangles to rest against. Never use the lower edge of the T square.

Thumb Tacks are used to secure the paper to the drawing board. Tack the upper left-hand corner first. The upper edge of the paper should then be lined up with the upper edge of the T square in order to get the paper placed squarely on the board and the lower right-hand corner of the paper carefully tacked, keeping the paper flat and smooth when tacking the other two corners. If the drawing should be removed from the board before it is finished and then replaced for further work, line up the longest horizontal line of the drawing with the T square instead of using the upper edge of the paper as when the paper was first placed on the board.

The Drawing Board should be made of clear, straight-grained, thoroughly seasoned white pine and it ought to be at least three-fourths of an inch thick, the other dimensions being about 16″ by 22″.

Pencils should be HH and HHHH. Sharpen the HH pencil to a round point on the plain end of the pencil and use for making letters, figures, arrowheads and sketches. Sharpen the HHHH pencil to a chisel shape point on the plain end of the pencil and use for drawing fine straight lines with the flat side of the lead against the guiding edge of the T square or triangles.

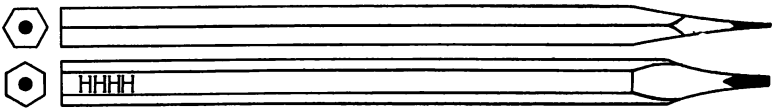


FIGURE 1.

Draw very fine lines but do not press hard enough on the pencil to make it cut into the paper. Figure 1 illustrates the proper way of sharpening pencils to the chisel shape point.

Triangles. By using the triangles against the upper edge of the T square, lines may be drawn at angles of 30°, 45°, 60° and 90°, to the horizontal lines made by drawing against the upper edge of the T square. By placing one triangle against the other, lines may be drawn at angles of 15° and 75° to the horizontal lines. The triangles are known as the *30/60 degree triangle* and the *45 degree triangle.* Also use the edge of the triangles as a guiding edge for ruling all other straight lines of the drawing which may be drawn at different angles to the horizontal lines than those described. Figure 2 shows the use of the triangles in connection with the T square.

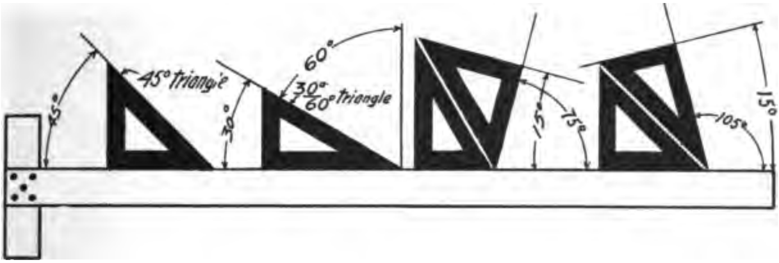


FIGURE 2.

The Compass is used for drawing circles and arcs of circles. It should be adjusted so that the pen or pencil points and the needle point are the same length. The pencil point may be sharpened to a round point or ground on the outside, by using a piece of fine sandpaper, emery cloth or file, at an angle of about 30° to the inside. This gives a very fine working point. When using the compass, hold in the right hand, and for exact placing on the paper direct with the left hand. Hold the compass at the top and roll the handle between the thumb and the first two fingers. The starting position should be such that the entire circle can be swept with one continuous stroke by moving the thumb forward and around without shifting the hold on the compass. But little pressure is necessary; whatever pressure is necessary apply on the pen or pencil points, not on the needle point. The lengthening bar is used when drawing arcs and circles of large radii. The *spring bow divider*, *bow pencil* and *bow pen* are used for smaller work than can be done conveniently with the larger instruments.

The Dividers are similar to the compass but have two sharp steel points. They are used for dividing lines into equal parts and transferring distances or measurements from the scale. They are handled in the same manner as the compass.

Scale. The scale is not intended to be used as a ruler but simply to take measurements from. For full size drawings it is usually graduated into inches and the fractional parts of an inch, as fine as thirty-seconds and sometimes sixty-fourths or hundredths of an inch. The size of an object will not always permit of its being represented full size and so it becomes necessary to draw it "*half size,*" "*quarter size,*" etc.—*i.e.*, each half or quarter inch, as the case may be, on the drawing represents or equals one inch of the object. The scale is usually graduated for this purpose into scales of various parts of an inch, each representing one inch or one foot, such as ½" equals 1 inch, or 1" equals 1 foot. A statement should always be made on the drawing giving the scale to which it is made and all dimensions must be given as though the drawing were made full size.

Curve Ruler. If a curve, not an arc of a circle, is to be drawn, first sketch the outline with a pencil and then apply the curve ruler to correct the sketched line. When inking, be careful to match as much of the curved line as possible with the ruler. When the line seems to leave the ruler, stop and match as before; this time being careful to have a part of the ruler run back over the portion of the line just finished so that the result will be a smooth sweeping curve.

Ruling Pen. Hold the pen upright with slight inclination in the direction of the line to be inked, between the thumb and first two fingers and the thumbscrew turned away. Steady the hand by resting it on the third and fourth fingers. Never use the ruling pen freehand but always against a guiding edge, T square or triangle, which should be placed so as to come under the hand holding the pen. Place the guiding edge at least a thirty-second of an inch away from the line to be inked, for otherwise the ink will flow under the guiding edge and cause an ugly blot. *Draw from left to right, or from the bottom up.* When filling the pen, adjust with the thumbscrew so that the points barely come together. Hold the pen upright, points down, dip the quill into the ink and then insert it between the blades of the pen, letting the ink run down into the pen. Carefully remove any ink that may get on the outside of the pen and do not fill the pen to more than one-fourth of an inch in height. Adjust the pen for the proper width of line and try it several times on a scrap piece of paper in order to ascertain if the pen is working properly. The ruling pen should always be kept very clean, never allowing any ink to dry in the pen as this corrodes the blades and spoils them for good work.

TERMS AND DEFINITIONS USED IN MECHANICAL DRAWING

Mechanical Drawing should be considered a language; a "written language of lines" instead of letters, for it is a written language which is universal, because the same methods of representation are used by draftsmen of all nationalities, the only differences appearing in the finished drawings being in the notes which are written or lettered on the drawing in the language of the country in which it is made and in the dimensions given in the units of measurement used in that particular country.

Mechanical Drawing is the art of making drawings capable of representing all forms of construction as a whole or in detail so clearly and completely that workmen familiar with such drawings can make the construction exactly as it is intended to be made without any further instructions than those contained in the drawings themselves.

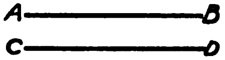
All forms of construction may be represented by some combination of *points*, *lines*, *surfaces and solids*, called *Geometrical Figures.*

Geometry treats of the properties, construction and measurement of geometrical figures; therefore it is the basis of all principles involved in the art of *Mechanical Drawing.*

It is therefore very essential for the pupil doing mechanical drawing to be familiar with the definitions used in geometry for the various kinds of lines and the different plane and solid figures known as geometrical figures.

A *straight line* is the shortest distance between two points; as *AB*.

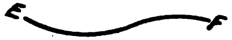
Parallel lines have the same direction and are equally distant apart; as *AB* and *CD*.



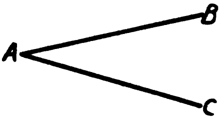
A *curved line*, or simply, a *curve* is a line no portion of which is straight; as *AB*.

Parallel curves are everywhere equally distant apart; as *AB* and *CD*.

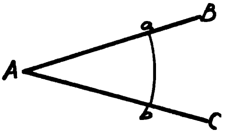
A *reversed curve* is one whose direction of curvature changes; as *EF*.



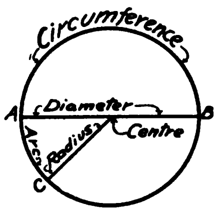
An *angle* is the difference in direction of two straight lines that meet or tend to meet; as *AB* and *AC*. The point of meeting, *A*, is called the *vertex* and the lines are called the *sides*.



An *angle* is measured by means of an arc of a circle described with the vertex of the angle as a center, and included within or between the sides of the angle.



The *circle* is defined as that portion of a plane surface bounded by a curve, called the *circumference*, all points of which are equally distant from a point within called the *center*.



—The Circle—

An *arc* is any portion of the circumference; as *AC*. The circumference of which the arc is a part is divided into 360 equal parts called *degrees.* The arc contains a certain number of these parts, or *degrees,* and the number of degrees indicates the *measure* of the angle.

The degree is divided into 60 equal parts called *minutes* and the minute is divided into 60 equal parts called *seconds.*

Degrees, minutes and *seconds* are denoted by symbols, thus 45 degrees, 17 minutes, 9 seconds is written *45°-, 17′-, 9″.*

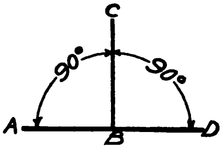
A *diameter* of a circle is a straight line drawn through the center, having its extremities in the circumference; as *AOB.*

A *radius* is a straight line drawn from the center to the circumference as *OA.*

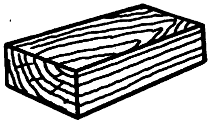
The *length of the circumference* is equal to the diameter multiplied by 3.1416. This constant is indicated by the Greek letter π (*pi*).

The *area* of the circle is equal to the square of the diameter multiplied by .7854; or—

The *area* of a circle is equal to the square of its radius multiplied by π (*pi*).

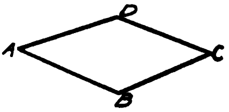


An angle as *ABC* or *CBD* having 90 degrees is called a *right* angle and the line *CB* is perpendicular to *AB* and *BD.*



A material body, for example a block of wood, occupies a limited portion of space. The boundary which separates such a body from surrounding space is called the *surface* of the body.

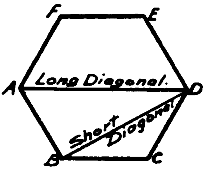
A surface has only two dimensions, length and breadth. A *plane surface* is a perfectly flat surface; as *ABCD.*



A *plane figure* is any part of a plane surface bounded by straight or curved lines.

A *polygon* is a plane figure bounded by straight lines only. The boundary lines are called sides and the sum of the sides or lines extending completely around the polygon is called the perimeter of the polygon.

A *diagonal* is a straight line in any polygon connecting vertices which are not adjacent. In regular polygons, diagonals are called *long* when they pass through the center, and *short* when they extend between parallel sides.



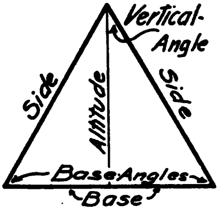
A *regular polygon* is one whose sides are all equal in length and whose angles are equal in measurement. Regular polygons are named from the number of their sides.

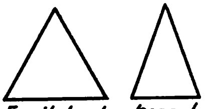
Number of sides.	Name.
Three	*Equilateral Triangle*
Four	*Quadrilateral, Square*
Five	*Pentagon*
Six	*Hexagon*
Seven	*Heptagon*
Eight	*Octagon*
Nine	*Nonagon*
Ten	*Decagon*
Twelve	*Dodecagon*

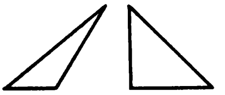
A *triangle* is a plane figure bounded by three straight lines. One of these lines, usually the one most horizontal, is called the *base* and the other two lines are referred to as the *sides*. The two angles at the ends of the base are said to be adjacent to the base and are called the *base angles*. The third angle, which is contained by the sides and is opposite the base is called the *vertical angle*.

The *height* or *altitude* of a triangle is the perpendicular distance from the vertex or upper angular point, to the base.

In every triangle, any two sides are together longer than the third side and the three angles added together equal 180°, or two right angles.




Equilateral Isosceles


Scalene Right-Angled

—Triangles—

Triangles are classified according to the magnitude of their angles or the length of their sides.

An *equilateral* triangle has all three sides equal.

An *isosceles* triangle has two of its sides equal.

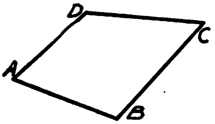
A *scalene* triangle has all three sides unequal.

A *right-angled* triangle has one of its angles a right angle. The side opposite the right angle is called the *hypotenuse*.

An *obtuse-angled* triangle has one of its angles greater than a right angle.

An *acute-angled* triangle has each of its angles less than a right angle.

A *quadrilateral* is a portion of a plane bounded by four straight lines; as *ABCD*.



-Quadrilateral-

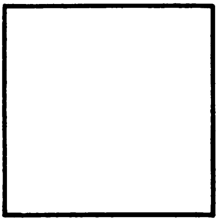
A *parallelogram* is a quadrilateral whose opposite sides are equal.

—Parallelogram—

A *rectangle* is a parallelogram whose angles are right angles.

—Rectangle—

A *square* is a rectangle whose sides are equal.



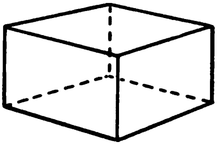
—Square—

A *solid* is that which has three dimensions.

A *polyhedron* is a solid bounded by polygons.

A *prism* is a polyhedron, two of whose faces are equal polygons lying in parallel planes, having their homologous sides parallel, the other faces being parallelograms.

The equal and parallel faces of a prism are called the *bases* and the other faces are called the *lateral faces*.

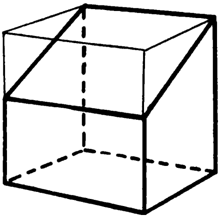


-Prism-

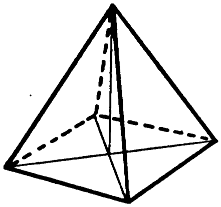
A prism is called *triangular*, *quadrangular*, *hexagonal*, etc., according as its base is a triangle, quadrilateral, hexagon, etc.

A *right prism* is a prism whose lateral edges are perpendicular to its bases.

A *truncated* prism is a portion of a prism included between the base and a plane not parallel to the base, cutting all the lateral edges of the prism.



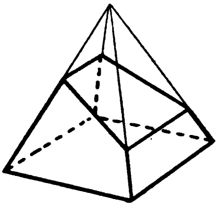
-Truncated Prism-



–Pyramid–

A *pyramid* is a polyhedron bounded by a polygon called the base and a series of triangles having a common vertex.

The *altitude* is the perpendicular distance from the vertex of the pyramid to the plane of the base.



Truncated Pyramid

A *pyramid* is called triangular, square, hexagonal, etc., as its base is a triangle, square, hexagon, etc.

A *truncated* pyramid is a portion of a pyramid included between the base and a plane cutting all the lateral edges.

All other necessary definitions are given in connection with the particular drawing problem in which they may be required.

WORKING DRAWINGS

Drawings from which objects are to be constructed are called *Working Drawings.* The making of a working drawing may be divided into three parts:—

1. The OUTLINE DRAWINGS showing the shape of the object in its different views and the arrangement of these views.

2. The DIMENSIONS stating the size of every part.

3. The LETTERING: i.e. the printed notes, explanations, directions and title.

Drawings are first made in pencil and, if a number of copies are desired, instead of inking the original, a tracing on thin transparent paper, or prepared tracing cloth, is made, from which any number of blueprints may be taken.

A drawing which shows every part of the object complete in its proper place is called an ASSEMBLED DRAWING.

A separate drawing of each part of an object is called a DETAIL DRAWING.

Drawings may be made to any convenient scale as "*full size,*" "*half size,*" "*quarter size,*" etc. Shop units are feet and inches and parts of an inch. The fractional scale of 8ths, 16ths, 32nds, and 64ths, is generally used although the decimal scale of 10ths, 100ths and 1000ths is often preferred for machine drawings.

LINES USED IN MECHANICAL DRAWING

The conventional lines used in mechanical drawing are illustrated in Plate II and no further definitions or comments are required other than those given in that plate. Figure 3 on this page illustrates very adequately the application of these conventional lines in the making of a working drawing.

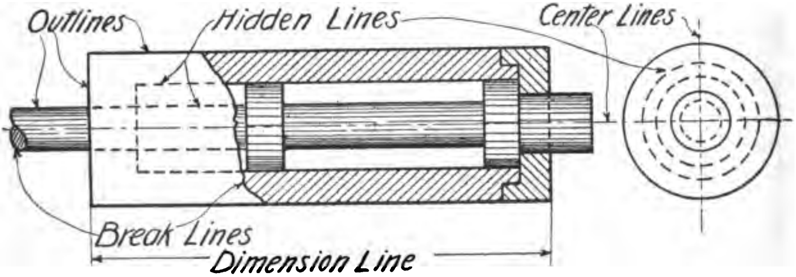
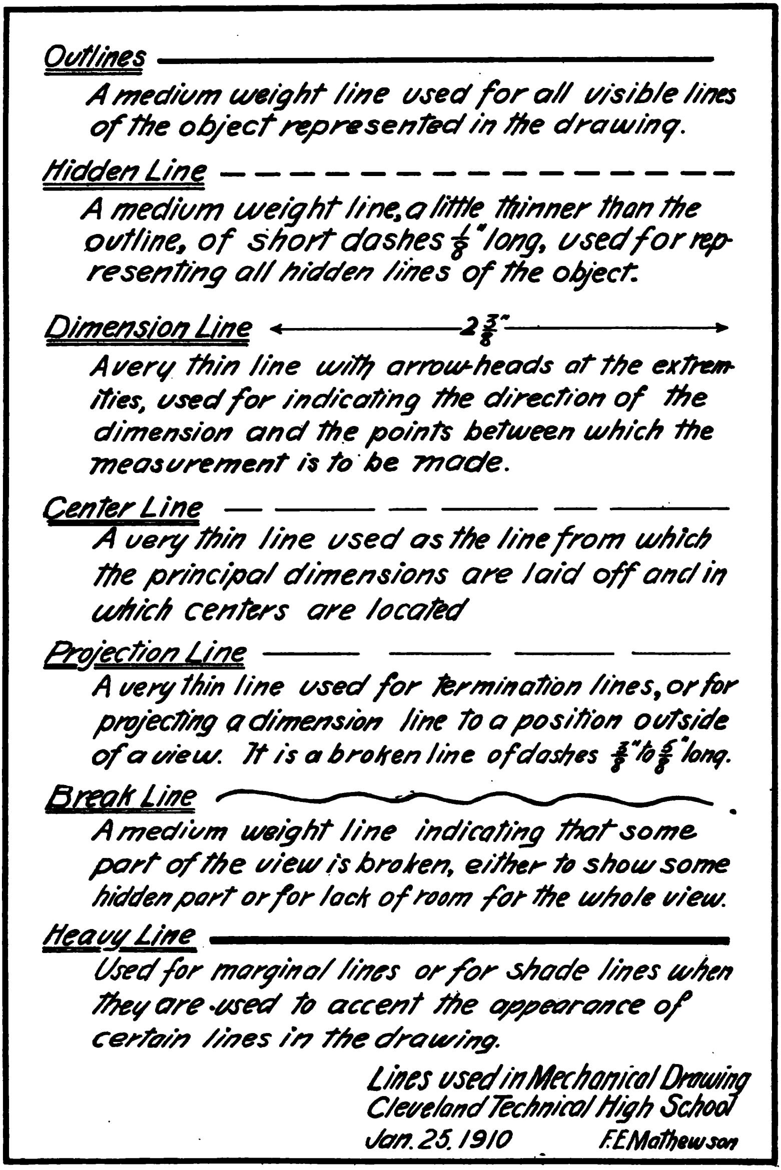


FIGURE 3.



Outlines

A medium weight line used for all visible lines of the object represented in the drawing.

Hidden Line

A medium weight line, a little thinner than the outline, of short dashes $\frac{1}{8}$" long, used for representing all hidden lines of the object.

Dimension Line

A very thin line with arrow-heads at the extremities, used for indicating the direction of the dimension and the points between which the measurement is to be made.

Center Line

A very thin line used as the line from which the principal dimensions are laid off and in which centers are located

Projection Line

A very thin line used for termination lines, or for projecting a dimension line to a position outside of a view. It is a broken line of dashes $\frac{3}{8}$" to $\frac{5}{8}$" long.

Break Line

A medium weight line indicating that some part of the view is broken, either to show some hidden part or for lack of room for the whole view.

Heavy Line

Used for marginal lines or for shade lines when they are used to accent the appearance of certain lines in the drawing.

Lines used in Mechanical Drawing
Cleveland Technical High School
Jan. 25. 1910 F. E. Mathewson

PLATE II.

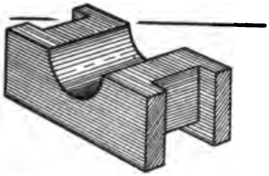


FIGURE 4.

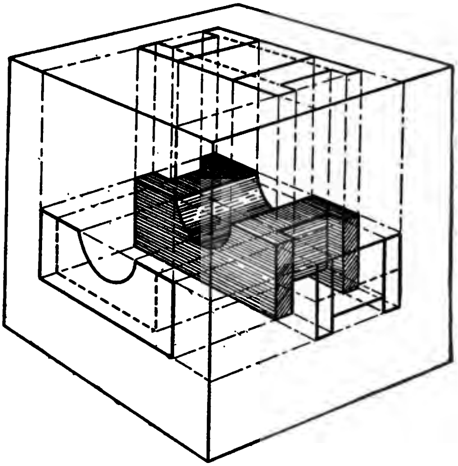


FIGURE 5.

THE ARRANGEMENT OF VIEWS

Drawings are always made on a flat surface or plane called the *picture-plane.* This picture-plane, represented by the surface of the drawing paper, is to be considered an imaginary, transparent plane, placed vertically in front of the observer, through which he is supposed to be looking and on the surface of which the picture is represented. If the drawing is made in such a way that the representation of an object shows it as it actually appears to the observer, as in Figure 4, the drawing is called a scenographic or perspective sketch. Such a drawing is worthless as a working drawing for the reason that, like a photograph, it does not show any of the lines of the object in their true lengths, nor is it possible to obtain any correct measurements of the object from a drawing of this character.

If there should be interposed between the object and the observer, three transparent planes, arranged so that they are perpendicular to each other as in Figure 5, and

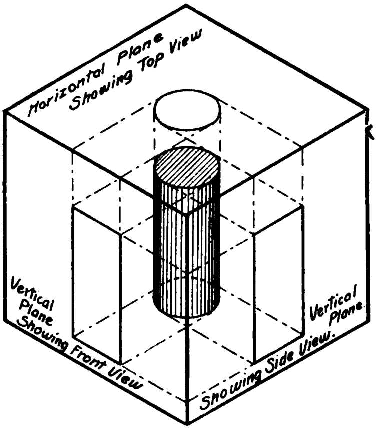

Horizontal Plane Showing Top View
Vertical Plane Showing Front View
Vertical Plane
Showing Side View.

FIGURE 6.

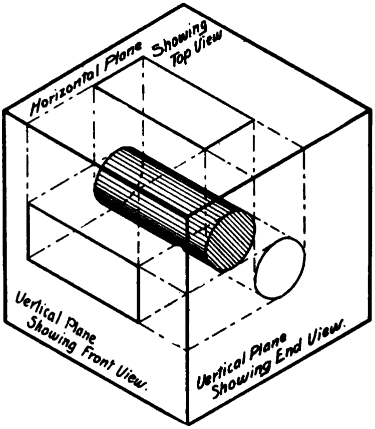

Horizontal Plane Showing Top View
Vertical Plane Showing Front View.
Vertical Plane Showing End View.

FIGURE 7.

with lines perpendicular to these planes projected from all the different points of the object to the planes, there can be produced on each plane the corresponding exact view of the object as it may be seen through the plane. A view of this kind is called an *Orthographic Projection* of the object on the plane. These planes are known as the *Horizontal* and *Vertical planes of projection.* The horizontal plane is always considered as being parallel with the surface of the earth and the vertical plane is always perpendicular to the horizontal plane. The front and side views, or elevations, are represented on the vertical planes and the top view, or plan, is represented on the horizontal plane, as in Figures 6 and 7. The vertical plane on which the side or end views are represented is usually called the side or profile plane.

In order to represent these planes on the flat picture-plane surface of the drawing paper, it is necessary to revolve them into such a position that their surfaces will lie in this one plane. Revolving the planes as illustrated in Figure 8, using the lines which separate the planes, as axes, will bring the top view always above the front view and the end or side view at the particular side of the front view that may be desired. A bottom view would thus be represented below the front view. The actual arrangement of the views on the surface of the drawing paper would be that shown in Figure 9. When making working drawings, the lines which divide the paper into the different spaces representing the interposed planes (which should always be thought of as purely imaginary planes), are never represented, so that the working drawing of the cylinder illustrated inside of the planes in Figure 6, should be made like Figure 1 of Plate V. Page 41.

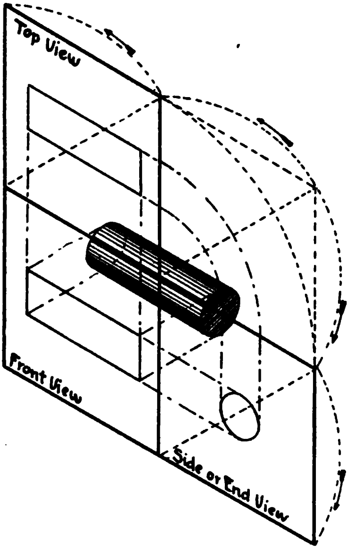


FIGURE 8.

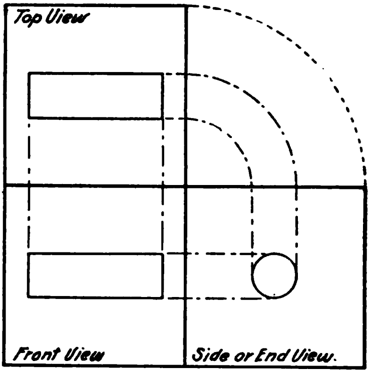


FIGURE 9.

Projection lines from one view to another are never used by draftsmen in making working drawings and the only line connecting the different views should be the center line of the object represented, from which the measurements for the drawing are usually laid off.

Sectional Views.

It is sometimes necessary, in order to show clearly some hidden part of an object, to represent a portion of the object by a sectional view, made by cutting away a part, or entirely through the object at a point which will illustrate best that part which cannot be well designated in the different views. These sectional views are usually designated on the drawing as "*Section at a-b,*" etc., the letters referring to the line drawn through or cutting a certain view at the place where it will show most clearly the construction of the hidden part. Sectional views are usually cross-hatched in order to distinguish them from other parts of the drawing. The lines which are used for cross-hatching are called section lines and they are usually drawn about one-sixteenth of an inch apart at an angle of 45° to the T square. Sections through the same part should have the section lines running in the same direction. Section lines should run in opposite directions when the section is shown through two separate and adjacent parts. Figure 10 illustrates a sectional view of an object. Sections may be shown by one kind of section-lining and the different materials of which the object is to be made indicated on the drawing. In many drafting rooms, however, a conventional section-lining is adopted for various kinds of material and some of these conventional forms are illustrated in Plate III.

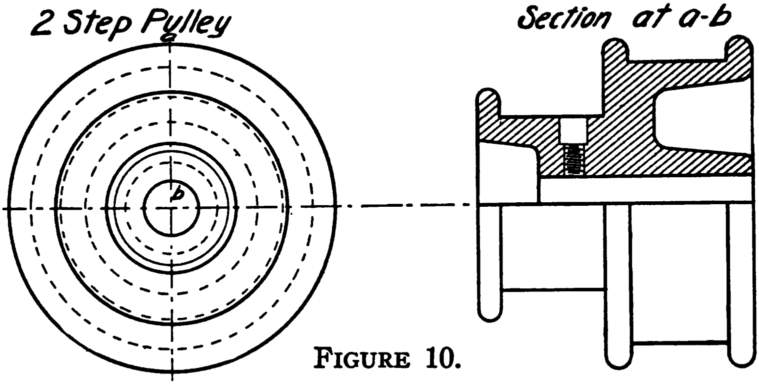
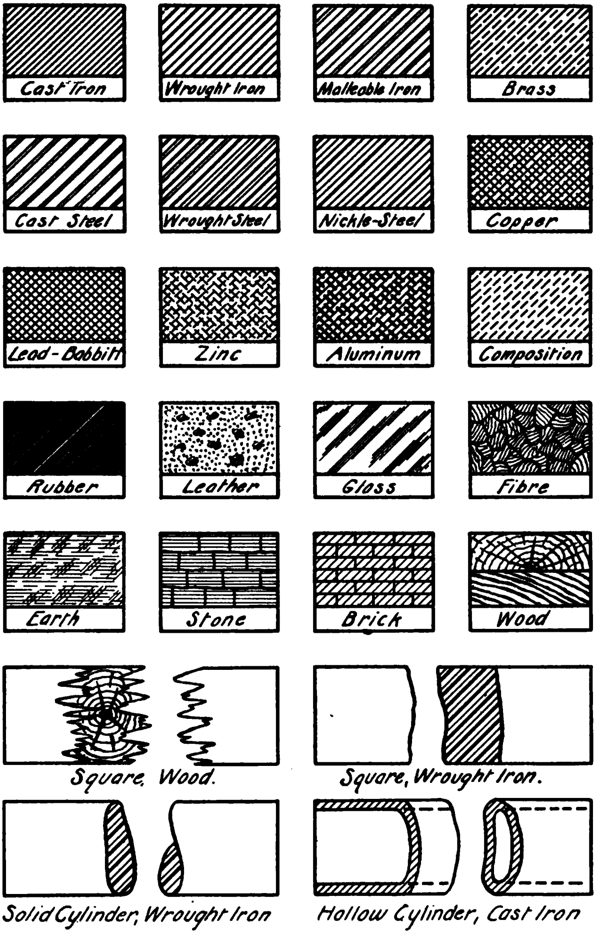


FIGURE 10.



Conventional Cross-sections

PLATE III.

DIMENSIONING WORKING DRAWINGS

Dimensions. The term "*dimensions*" used in connection with a drawing denotes the placing of measurements on the drawing in such a position that they will indicate the exact points at which the measurements are to be made. The term includes the figures, lines and arrowheads as indicated in Figure 11.

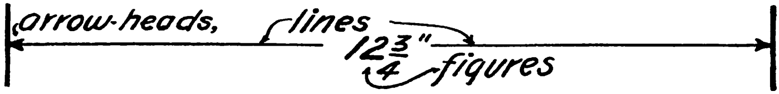


FIGURE 11.

The size of every part of an object may be indicated by the dimension lines and figures. The dimension lines show exactly from what point to what point the measurement is to be made. These lines are usually made a fine black line although red ink lines are sometimes used. Red ink lines on a tracing, print more faintly on blue process paper than black ink lines, thus having the effect of making the lines of the drawing which have been made with black ink stand out clearly with the dimension lines in the background.

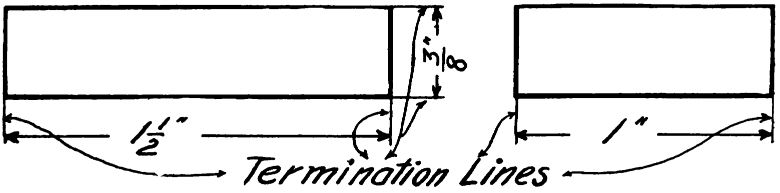


FIGURE 12.

Termination lines, or extension lines, must always e made perpendicular to the dimension line and should xtend a slight distance beyond the dimension line. They how between which parts of the object the measurement s to be taken.

Arrowheads at the end of dimension lines should be made very neatly and should look like arrowheads. When carelessly made they spoil the appearance of the drawing. Figure 13 illustrates the correct and incorrect methods of drawing arrowheads.

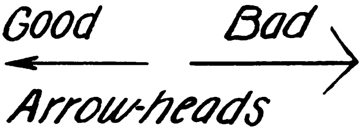


FIGURE 13.

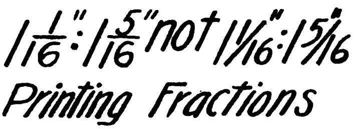


FIGURE 14.

Figures used for dimensions should be made very carefully, round and full and not cramped or crowded together. In printing fractions the line between the numerator and the denominator, called the vinculum, should always be made parallel to the dimension lines. The fractions shown with the oblique line in Figure 14 might easily be mistakenly read *eleven-sixteenths* or *fifteen-sixteenths* instead of the sizes intended by the draftsman. All figures and arrowheads should be made with black ink on drawings and tracings.

Any dimension less than one foot should be given in inches, not as a fractional part of a foot. Any measurement less than one inch should be given in fractional form when the denominator is 2, 4, 8, 16, 32, or 64 which are the fractional parts of an inch to be usually found on scales in common use. Any other fractional measurement should be given as a decimal part of an inch. If a dimension is given in feet and inches, it should read thus—*2′-6½″*. If a dimension is given in even feet, it should read—*16′-0″*. If the dimension is given in feet and a fraction of an inch, it should read—*15′-0¾″*.

"*Overall*" dimensions indicate the greatest dimensions of an object in any direction and are divided and subdivided into such divisions as may be found necessary. (Figure 15.) Great care must be observed to see that the total of all of the shorter dimensions of the subdivisions is equal to the

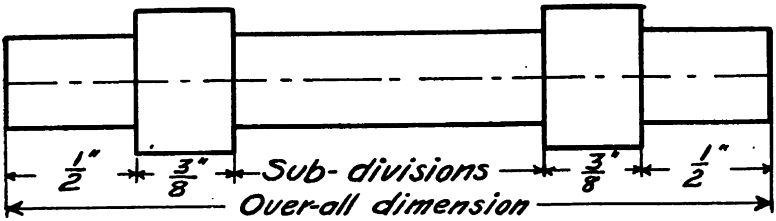


FIGURE 15.

longer or overall dimension. Overall dimensions are of great importance as they save the workman the necessity of footing up or adding together a number of smaller dimensions when getting out his rough material.

There should be given just enough dimensions to remove any doubt as to the size of parts or of the whole construction and they ought not to be repeated in other views except when they will aid in making the drawing easier to understand.

A dimension should be so placed on the drawing that it will not interfere with the drawing or be confused

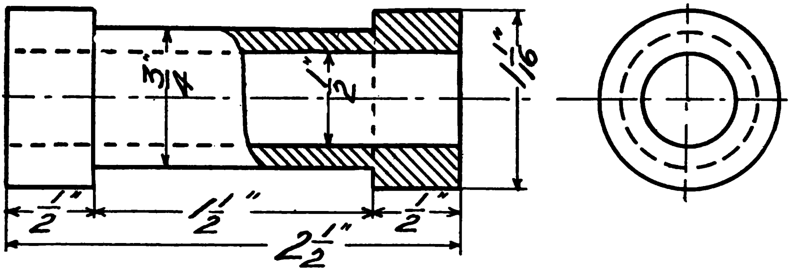


FIGURE 16.

with any other dimensions. The space dimensioned should be so chosen as to avoid any necessity for addition or subtraction by the workman in executing the work.

Drawings are usually made to scale; but if scale and dimensions do not agree, the dimensions are always assumed to be correct. In many shops, workmen are never allowed to measure a drawing but must use only the dimensions given on the drawing. This is necessary owing to the universal use of blueprints, which shrink considerably in the process of washing and drying, thus making them differ quite a little in size from the original tracing from which they are made. Therefore it is very important that all dimensions be carefully placed and checked before the drawing is blueprinted and sent to the shop.

For all linear measurements, the dimension lines must be made perpendicular to the parallel lines or surfaces between which the measurement is taken. (Figure 16.)

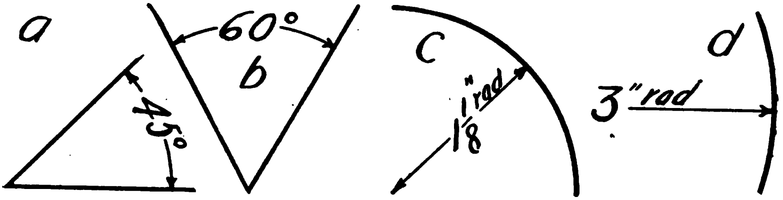


FIGURE 17.

For angular measurements the dimension lines must be arcs described with the vertex of the angle as a center. (*a* and *b*, Figure 17.) For dimensioning the radius of an arc of a circle, the dimension line is to be drawn from the center from which the arc was described. (*c* and *d*, Figure 17.)

For diameters of circles the dimension line must be a diameter other than the horizontal or vertical diameters of the circle or the center line drawn through the circle. (*a*, Figure 18.) The dimension line may also be drawn parallel with a diameter of the circle and perpendicular to parallel tangents drawn at the extremities of the diameter used for this purpose. (*b* and *c*, Figure 18.) Dimension lines should not be closer than one-fourth of an inch to any line of the object or other dimension lines, and should not cross each other when it can be avoided. Whenever possible, dimensions should be placed outside of the lines of the

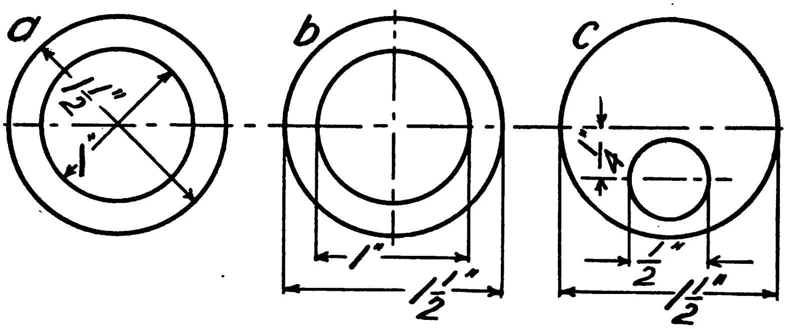


FIGURE 18.

object. Figures 19 and 20 illustrate the methods employed in placing dimension lines where conditions do not always allow the foregoing directions for placing dimensions to be applied.

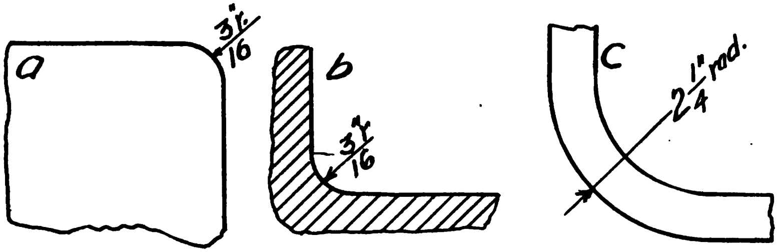


FIGURE 19.

Finish. When a part of the object is to be finished, a small "*f*" is printed on the line representing the surface to be finished. When a special kind of finish is desired a note stating the character of the finish should be printed adjacent to the surface requiring such finish. When the piece is to be finished all over, it should be stated on the drawing thus: "*f all over.*" Place cross bar of "*f*" on the ine to be finished as in "*e*," Figure 20.

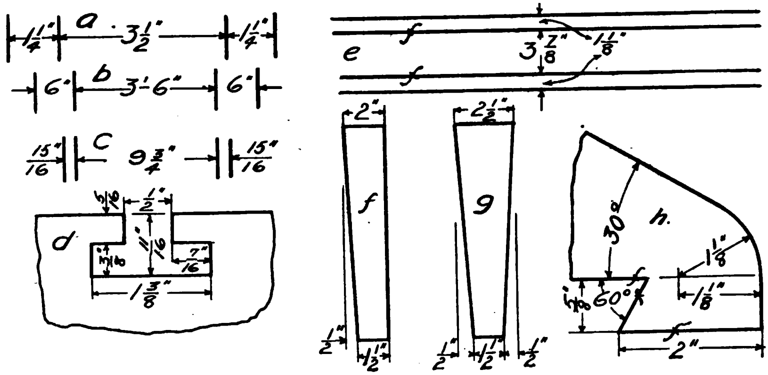


FIGURE 20.

Suggestions to follow when making working drawings:

If one view shows a larger portion of the object in its true shape and size than any other view, start that view first.

Lay out all center lines of views before drawing any outline of the object. Estimate the space required for each view, allowing space enough for dimension lines between the views and build up each view about its center lines. Project measurements from one view to another to save work with the scale. It is often impossible to complete one view at a time. In many cases it is necessary to carry two or more views along simultaneously, drawing main outlines first—details last.

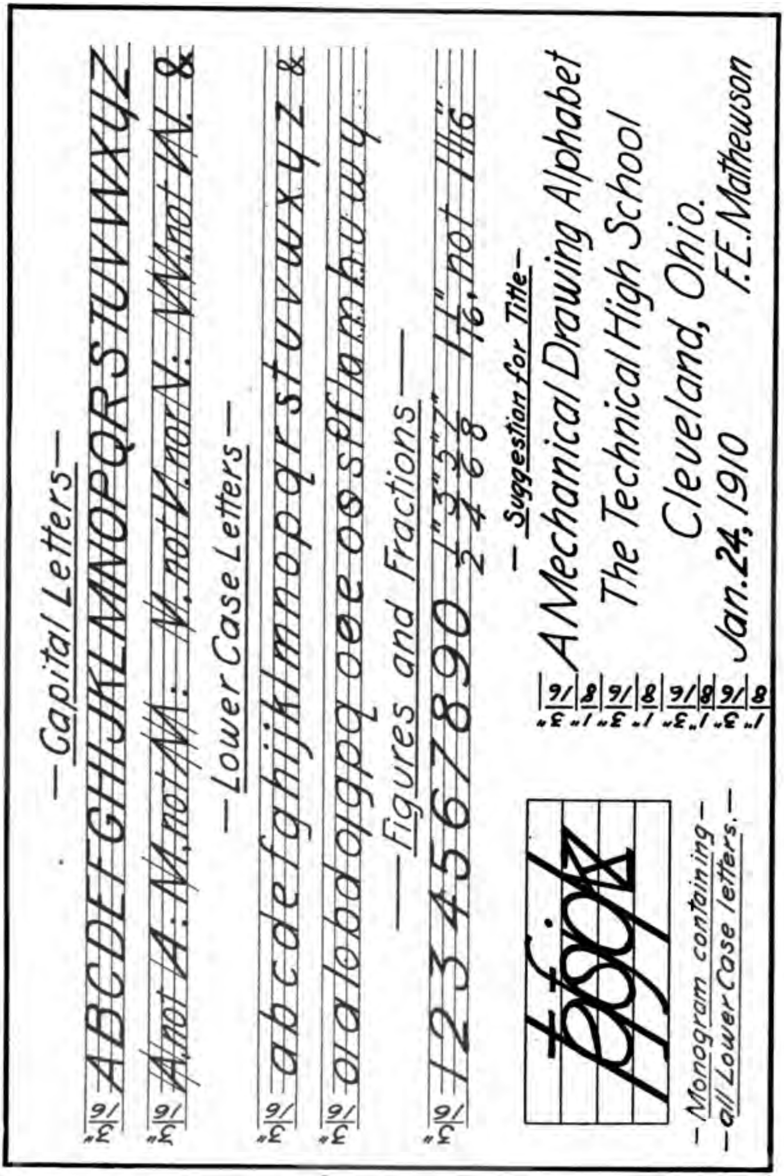
Be sure that important measurements to center lines, etc., are correct before putting in dimensions of smaller details depending upon them. If a dimension is altered, change at once all other dimensions relating or depending upon it to agree with the changed dimension.

Place all dimensions on the drawing before doing any section-lining. Section-lines should not be drawn parallel to any line of the object.

Order of inking. *Marginal lines, arcs of circles, irregular curves, straight lines of the object, center lines, dimension lines, dimensions, section lines, notes, title.*

The Blueprint. If an original drawing is used in the shop it is liable to become soiled, mislaid and perhaps destroyed, thus leaving no permanent record of the construction for future reference, which in most instances is necessary, especially in manufacturing establishments. To make duplicate drawings would be expensive and errors might occur in copying the original drawing. The simplest and most effective method of accurately duplicating drawings is by the "*blueprint process.*" Blueprint paper is a white paper coated with a solution which is sensitive to light. If protected from light the coating may be easily removed by soaking the paper in water, but if exposed to light, the coating turns a bluish gray color, which, when placed in water, turns a blue color, insoluble in water.

For blueprinting, a wooden frame set with glass, and having a removable back with a felt pad is required. A tracing from the original drawing should be made on transparent paper or cloth. This tracing is placed in the frame with the ink lines toward the glass. The prepared paper is then placed with the sensitized surface next to the tracing, followed by the felt pad and the back of the frame which is fastened in place making a close smooth contact between paper, tracing and glass. The glass side of the frame is then placed in direct sunlight if possible, which passing through that part of the tracing not covered with ink lines, acts on the sensitized surface of the paper, but does not effect the part protected by the lines. After an exposure varying, according to the light and sensitiveness of the coating, the print is taken from the frame and thoroughly washed in running water which removes the superfluous sensitizing solution, leaving white lines on a blue ground. After washing, hang the print up to dry. As many prints may be made as required and the tracing preserved for future use. If the printing time has been too short the ground washes out to a pale blue color making a weak contrast to the lines. If exposed too long, the light may work through the lines of the tracing and in the print the lines will wash out a pale blue on a ground too dark or gray in color.



- Capital Letters -
ABCDEFGHIJKLMNOPQRSTUVWXYZ
A, not A. M, not M. V, not V. W, not W. &
- Lower Case Letters -
abcdefghijklmnopqrstuvwxyz &
— Figures and Fractions —
1234567890 1/2 3/4 7/8 1" 3" 5" 7" 1 1/16, not 1 1/16
- Suggestion for Title -
A Mechanical Drawing Alphabet
The Technical High School
Cleveland, Ohio.
Jan. 24, 1910
F.E. Mathewson
- Monogram containing -
- all Lower Case letters. -
3/16"
1/8"
3"

PLATE IV.

Lettering.

It is very necessary that draftsmen should be able to do freehand lettering quickly and neatly. Drawings usually have a title and also contain necessary notes and figures. Poor lettering detracts from the appearance of what otherwise might be an excellent piece of work. A simple letter that can be executed easily and which is admirably suitable for mechanical drawing is illustrated on the opposite page. (Plate IV.) This style of letter is an inclined Gothic and it is very similar to the system of lettering known as the *Reinhardt Alphabet.* The capital letters, or "upper case" are three-sixteenths of an inch high and the general slope is from 60° to 75°. All the small letters are made up of parts of the ellipse and a straight line drawn tangent to the ellipse. The small letters, or "lower case," are two-thirds the height of the capitals, the ascending letters being made the height of the capitals and the descending letters extending the same distance below. Always draw very light pencil guide lines for the height of the letters. These lines will insure uniformity of height and also aid materially in forming and spacing the letters. All lettering should be done freehand and first outlined in pencil, having the pencil sharpened to a fine round point. Special attention should be given to practicing the making of the strokes of which the letters are composed and to the making of the figures, having them round and full-bodied. For inking use a writing pen with very little ink, taking great care not to press hard enough on the pen to spread the points. Take special care to keep the slope of the letters uniform. Let the result be clean cut, well formed, properly spaced letters.

Drawing Plates.

All exercises and problems in this book are planned for two different sizes of drawing paper which are designated as *A* and *B* drawing plates.

THE A PLATE is intended to be used in connection with the loose leaf note book having pages 8″×10½″, for all drawings of woodturning exercises and other small drawings made

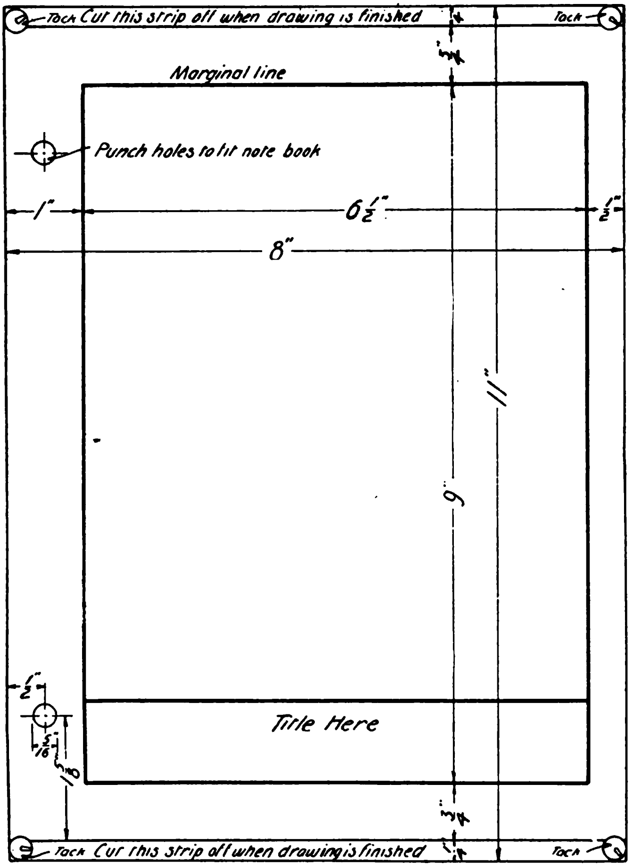

Tack Cut this strip off when drawing is finished
Tack
Marginal line
Punch holes to fit note book
1"
6½"
½"
8"
11"
9"
¾"
Title Here
½"
5/16"
1/8"
Tack Cut this strip off when drawing is finished
Tack

FIGURE 21-A

for the shops. The layout for this plate is given in Figure 21-A. The size of the paper is 8×11", which allows space for a narrow cutting strip at both the top and bottom of the plate. The left-hand margin is made 1" wide to allow space for punching holes to fit the note book. The top and lower margins are each ¾" wide and the right-hand margin is ½"

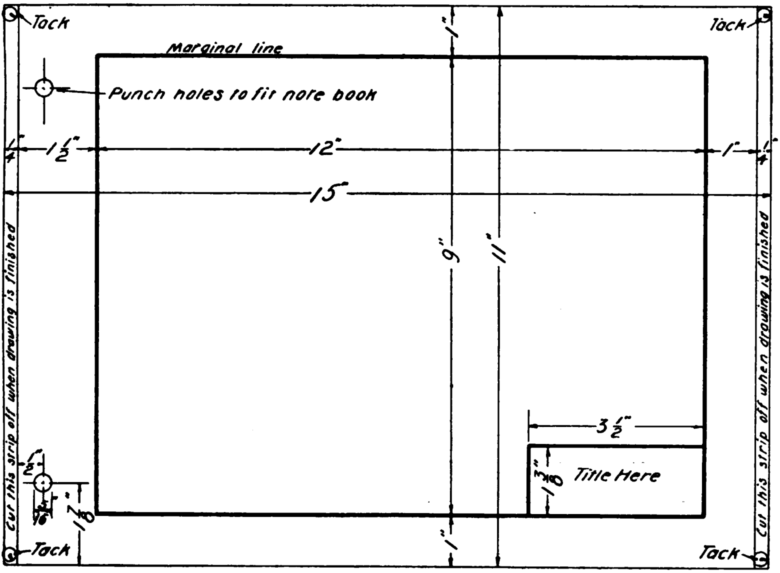

Tack
Tack
Marginal line
Punch holes to fit note book
1/4"
1 1/2"
12"
1"
1/4"
15"
9"
11"
1"
1"
Cut this strip off when drawing is finished
Cut this strip off when drawing is finished
3 1/2"
1 3/16"
Title Here
1/2"
5/16
1 7/8
Tack
Tack

FIGURE 21-B

wide. A space $1\frac{1}{16}''$ wide above the lower margin is reserved for the title, and the arrangement and spacing of the lettering of the title is illustrated in Figure 22. The space inside the margins is called the working space of the plate.

THE B PLATE is intended for drawings requiring a larger working space than that afforded in the A plate and unless otherwise stated all problems preceding page 103 are to be worked out on this size plate. The layout for this plate is given in Figure 21-B. The size of the paper is $11''\times15''$ which allows space for the cutting strip at each end of the plate. The left-hand margin is to be $1\frac{1}{2}''$ wide and the other three margins are each $1''$ wide, leaving a working space of $9''\times12''$. The space allowed for title is $1\frac{3}{8}''\times3\frac{1}{2}''$ and this space should always be placed in the lower right-hand corner of the plate if possible. If necessary it may be placed in the upper right-hand corner of the plate.

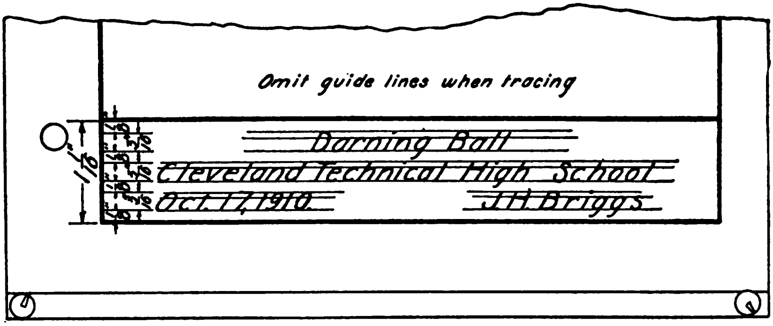

Omit guide lines when tracing
Darning Ball
Cleveland Technical High School
Oct. 17, 1910
J.H. Briggs
1 1/16"

FIGURE 22.

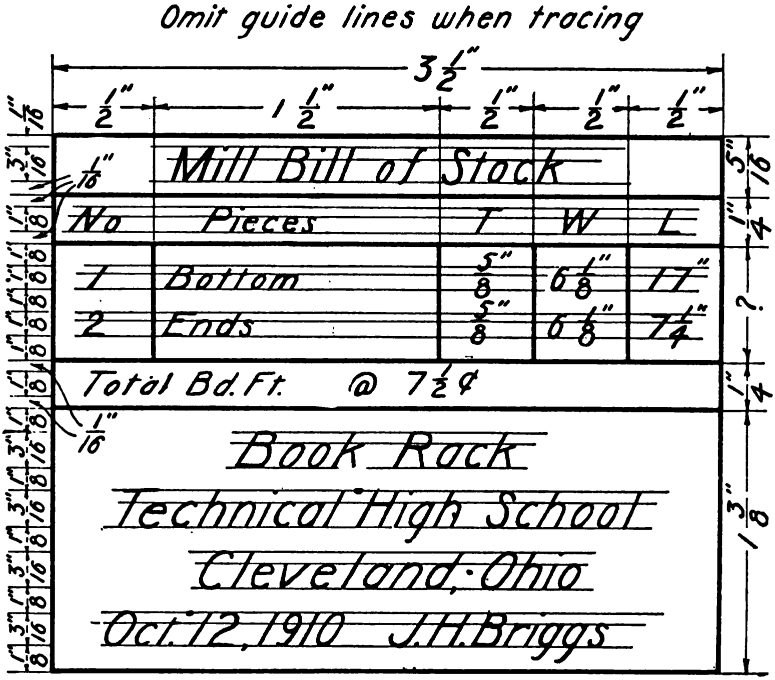


FIGURE 23.

GEOMETRICAL CONSTRUCTION OF PLANE FIGURES AND TYPE SOLIDS WITH THEIR PRACTICAL APPLICATION IN PROBLEMS FOR WORKING DRAWINGS

The Cylinder. A cylinder is a round body of uniform diameter which is bounded by a cylindrical surface and two parallel circular planes called the bases. A right circular cylinder may be generated by the revolution of a rectangle (*abcd*, Figure 24) about one of its sides, *ab*, as an axis.

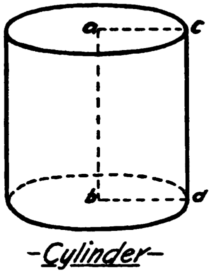


FIGURE 24.

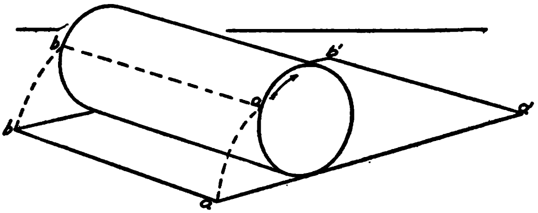


FIGURE 25.

Drawing Problem 1. Make a working drawing of two views of a cylinder which is 2¼″ diameter, 3¾″ high, and also lay out a pattern for the surface of the cylinder. (Plate V, Figures 1 and 2.)

If the cylinder is placed inside of the transparent planes in a vertical position as in Figure 6, Page 23, it will be noted that the front and side views are exactly alike when projected from the cylinder to the planes. If the cylinder is placed in a horizontal position (Figure 7), then the front and top views are alike in both representation and dimensions. For this reason, when representing cylindrical forms, it is not necessary to draw more than two views, one of which shall be the circle representing the base of the cylinder.

It is even permissible to omit the circle if the word *diameter*, or its abbreviation, *dia.*, is included in the dimension stating the size of the cylinder in this respect. When making this drawing, locate the center lines and then draw the circle representing the base or end of the cylinder. From each end of the horizontal diameter of this circle may be projected lines for the front view and that view completed by drawing the horizontal lines, at the proper distance apart, which represent the edges of the bases as they would appear in this view.

If the cylinder should be laid down on its curved surface and rolled along, or over, a flat plane as in Figure 25, starting with the point *a* on the cylinder tangent to the point *a* of the plane, the distance rolled off on the plane by one revolution of the cylinder would be equal to the length of the circumference of the circle forming the base of the cylinder. If a rectangular piece of paper with the length *a-a′* equal to the circumference of the base, and the width *a-b* equal to the height of the cylinder, should be rolled or curved until the edges *a-b* and *a′-b′* meet, the result would be a hollow cylindrical form. The rectangular piece is a pattern of the surface of the cylinder and is known as a developed surface. Its area would be its length multiplied by its width. The number of cubic inches contained in a cylinder is found by multiplying the area of the base by the height.

Draw the top and front views, the development of the surface, and place all necessary dimensions.

EXAMPLES. 1. How many cylinders, without ends, of the size called for in the foregoing problem, could be made from a sheet of XXX tin, 16″ by 22″?

2. If this cylinder were made solid of cast-iron weighing 450 lbs. per cubic foot, what would it cost at 3½ cents per pound?

—Cylinder—

Length of developed surface = ...

Area of developed surface = ...

Area of circular ends = ...

Cubical contents of cylinder = ...

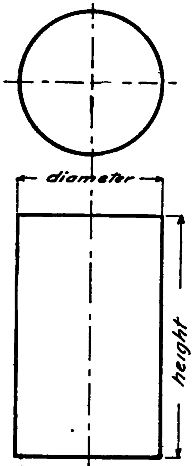


Fig. 1-

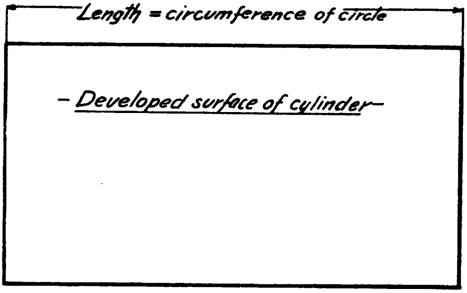

Length = circumference of circle
- Developed surface of cylinder-

Fig. 2-

—Cylindrical Rings—

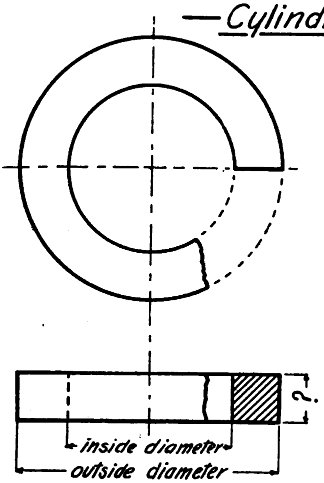


Fig. 3-

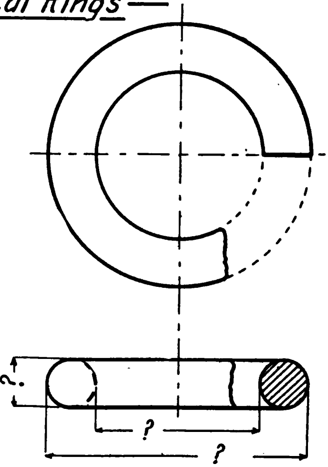


Fig. 4-

PLATE V.

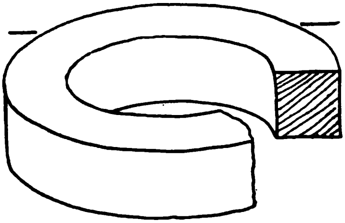


FIGURE 26.

Drawing Problem 2. (a) Make a drawing of a circular ring, Figure 26. The outside diameter is 4″ and a piece broken out shows that the section is 1″ square. What is the inside diameter of the ring? (Figure 3, Plate IV.)

(b) Make a drawing of a similar ring having a circular section 1″ in diameter. (Figure 4, Plate IV.)

EXAMPLE. Calculate the weight of each ring if made of cast-iron.

Drawing Problem 3. Make top and front views of any one of the cylindrical forms illustrated in Figure 27. In each of these forms the largest diameter is 2″ and the smallest diameter is 1¼″. The overall length is 4½″. The length of *b* is divided into three equal parts. In *c*, the length of the smaller middle part is four times the length of the larger part at each end. In *d*, the length of the smaller part and the depth of the hole are each one-third the entire length of the cylindrical form.

EXAMPLE. Calculate the weight of each if made of cast-iron.

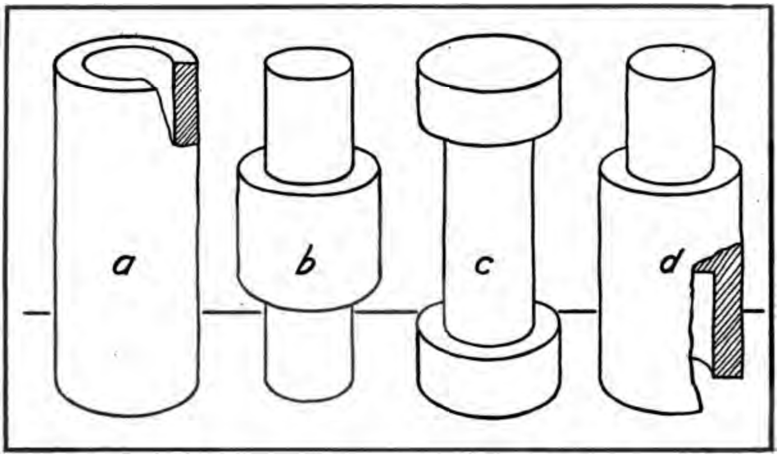


FIGURE 27.

The Square. PLATE VI. The *Square* is a plane figure having four straight sides equal in length and all included angles right angles.

The *Area* (*a*) of the square is obtained by multiplying the length by the breadth. As these are equal, this therefore amounts to squaring the length of the side (*s*).

Formula: $a = s^2$

The *Diagonal* (*d*) of the square is equal in length to the square root of two times the square of the side.

Formula: $d = \sqrt{2 \times s^2}$: or $d = s\sqrt{2}$

$\sqrt{2} = 1.414$

The length of the side of a square may be determined by finding the square root of the area.

Formula: $s = \sqrt{a}$

When only the length of the diagonal is known, the length of the side may be determined by finding the square root of one-half of the square of the diagonal.

Formula: $s = \sqrt{\frac{d^2}{2}}$: or $\frac{d\sqrt{2}}{2}$

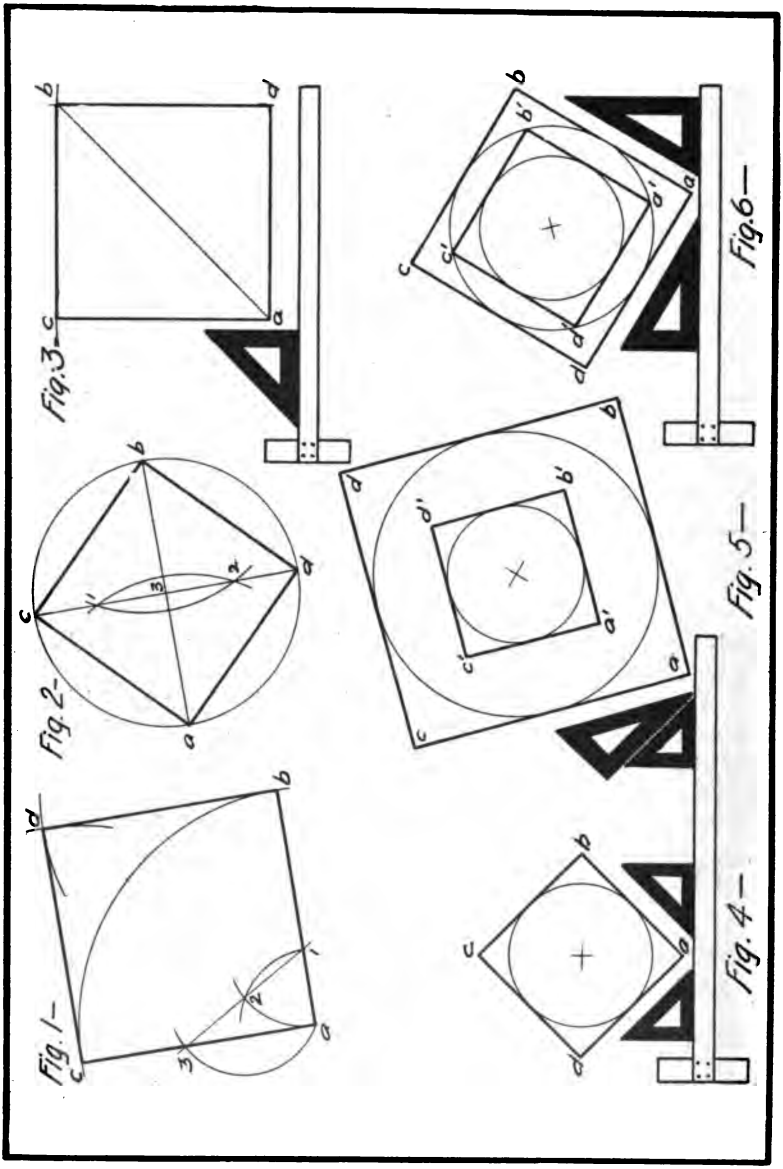


Fig. 1–
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c
d
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2
3
Fig. 2-
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b
c
d
1
2
3
Fig. 3-
a
b
c
d
Fig. 4-
a
b
c
d
Fig. 5–
a
b
c
d
a'
b'
c'
d'
Fig. 6–
a
b
c
d
a'
b'
c'
d'

PLATE VI.

Geometrical Construction of the Square

Figure 1. When the length of the side *ab* is given. With *a* as center and any radius, as *a1*, draw arc from *1* over *a*. With *1* as center draw arc *a2*. With *2* as center draw arc from *a* over *2*. Draw line *1-3* passing through *2*. Draw *ac* perpendicular to *ab* passing through *3*. With *a* as center draw arc *bc*. With *b* and *c* as centers, with radius *ab*, draw arcs intersecting at *d*. Draw *cd* and *bd*.

Figure 2. When the length of the diagonal, *ab* is given. With any radius greater than one-half the length of *ab*, and *a* and *b* as centers, draw arcs intersecting at *1* and *2*. Draw bisecting line through *1* and *2* giving *3* on *ab*. With *3* as center and radius *3b* draw circle cutting bisector at *c* and *d*. Draw *acb* and *adb*. Figures 3, 4, 5, and 6 show various methods of constructing the square in different positions, using the T square and triangles.

Examples. 1. On any line not parallel with the T square, construct geometrically a square having an area of 6.25 square inches. (Figure 1.)

2. On any diagonal not parallel with the T square, construct geometrically a square with sides 2⅛″ long. (Figure 2.)

Using T square and triangles construct:—

3. A square with a diagonal 2¾″ long at 45° to the T square. (Figure 3.)

4. A square having an area of three-fourths of the square in Example 3, and its sides at 45° to the T square. (Figure 4.)

5. Two squares as in Figure 5. The area of the inner square is 2¼″ which is one-fourth the area of the outside square. The lower sides of the squares are at 15° to the T square.

6. Two squares as in Figure 6. The side *ab* of the outer square is equal to the diagonal *a′c′* of the inner square. The area of the inner square is 1.5625″. What is the area of the outer square?

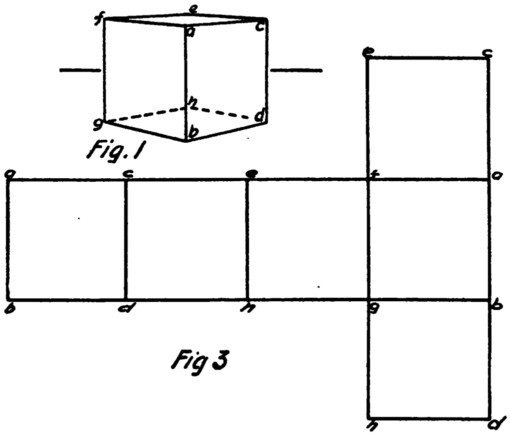

Fig. 1

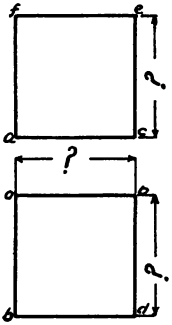

Fig. 2

Fig 3

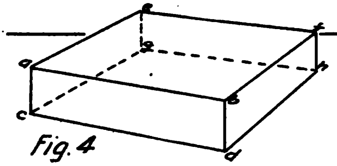

Fig. 4

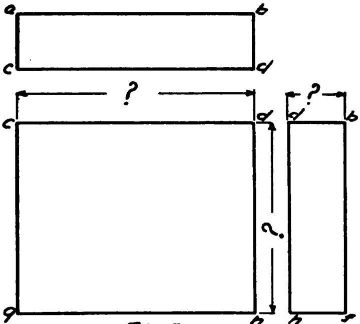

Fig. 5

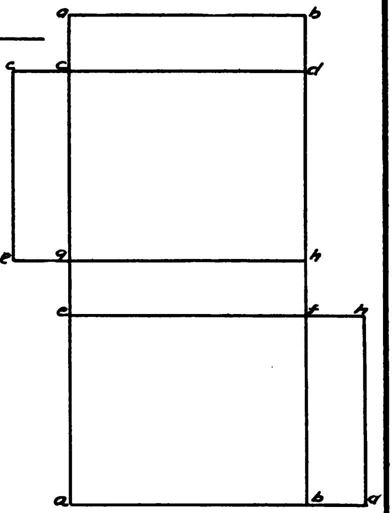

Fig. 6

PLATE VII.

The Cube. PLATE VII. The *Cube* is a right rectangular prism whose faces, six in number, are all squares.

The cubic contents of the cube are found by multiplying the area of the base by the height, or, because all dimensions of a cube are equal, by determining the third power of the one dimension (s).

Formula: *Cubical contents* $= s^3$*; or*

(length × *breadth* × *height)*

Figure 1 is a perspective sketch of the cube, and if placed as the cylinder in Figure 6, Page 23, its three views would appear on the planes all exactly alike. A working drawing showing but two views as in Figure 2 is all that is necessary to adequately represent the cube. As the six faces of the cube are exactly alike, its developed surface would contain the area of the six faces as in Figure 3.

Drawing Problem 4. Make working drawing and develop surface of a cube which contains 8 cubic inches. How many square inches in the developed surface of the cube?

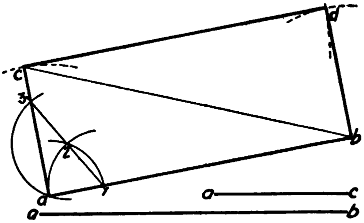

FIGURE 28.

The Rectangle. The *Rectangle* is a plane figure having four sides, with opposite sides equal in length and all included angles, right angles.

The *area* of the rectangle is equal to its length multiplied by its breadth.

The length of the diagonal (cb) may be obtained by finding the square root of the sum of the squares of the two dimensions of the rectangle. Referring to the drawing (Figure 28) the

Formula is: $cb = \sqrt{(ab)^2 + (ac)^2}$

GEOMETRIC CONSTRUCTION OF THE RECTANGLE. (Figure 28.) When the lengths of the two sides *ab* and *ac* are given and base of rectangle is to be at an angle to the T square. Erect a perpendicular at *a* as in Figure 1, Plate VI, and with radius *ac*, cut line at *c* from *a* as center. With same radius draw arc above *b* and with radius *ab*, center at *c* draw intersecting arc at *d*. Draw *cd* and *bd*.

The Rectangular Prism. PLATE VII. A right *Rectangular Prism* is a prism whose faces, six in number, are all rectangles and all opposite faces are equal.

Drawing Problem 5. Make working drawing of three views and develop surface of a rectangular prism shown in Figure 4 whose proportions of length, breadth and thickness are 4, 3, and 1. The thickness is ¾″.

EXAMPLES. 1. What is the number of cubic inches in this prism?

2. What would it weigh if made solid of lead which weighs 709.4 lbs. per cubic foot?

3. How many square inches in its developed surface?

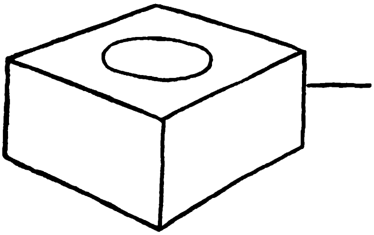

FIGURE 29.

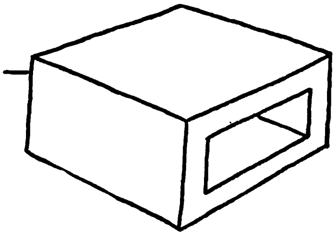

FIGURE 30.

Drawing Problems. Make working drawings of three views each of—

6. A rectangular block (Figure 29), 6¼″×5¾″×1½″, with hole 3″ diameter through block. Calculate the weight if made of brass weighing 523.4 lbs. per cubic foot.

7. A rectangular block (Figure 30), 5¾″×5½″×2¼″, with hole 4¾″×1½″, making a shell ⅜″ thick. Calculate weight if made of either cast-iron or brass.

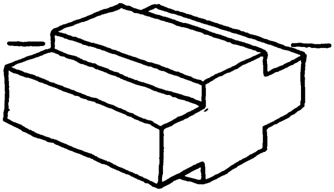

FIGURE 31.

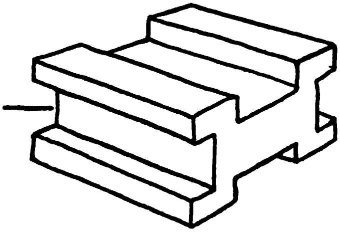

FIGURE 32.

8. A rectangular block of same dimensions as Problem 6 but with the corners cut out as in Figure 31. The space cut out is ⅜″×1⅜″ at each corner. Calculate number of cubic inches in block.

9. A rectangular block of same dimensions as Problem 7 but with grooves ¼″ deep by 3½″ wide in the largest faces and ¼″ deep by 1¾″ wide in the narrow faces, all located in the center of the faces as in Figure 32. Calculate the number of cubic inches in this block.

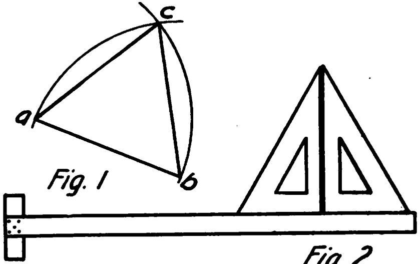

Fig. 1

Fig. 2

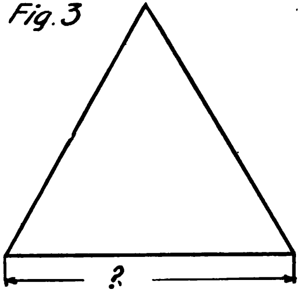

Fig. 3

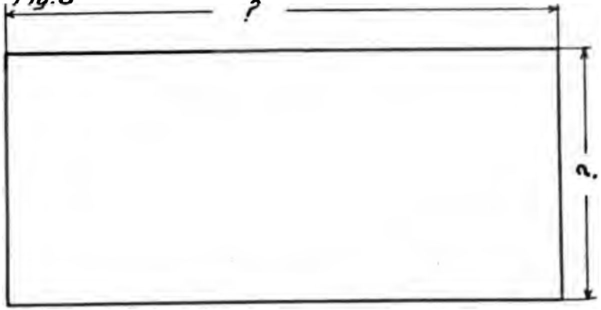

Fig. 4

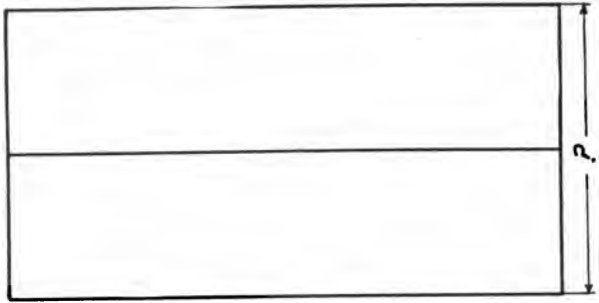

Fig. 5

PLATE VIII.

The Equilateral Triangle and Equilateral Triangular Prism. PLATE VIII. The *Equilateral Triangle* is a triangle having three equal sides and three equal included angles of 60° each.

Its geometrical construction is shown in Figure 1. With the length of the given side *ab* as a radius and *a* and *b* as centers, draw arcs intersecting at *c*. Draw *ac* and *bc*.

Its construction with triangles and T square is indicated in Figure 2.

The *altitude* is determined by dropping a line from the vertex *c* perpendicular to the base *ab*. (Figure 33.) This makes the line *ac* the hypotenuse of the right-angled triangle *adc* and the length *dc* is equal to the square root of the difference between the squares of *ac* and *ad*.

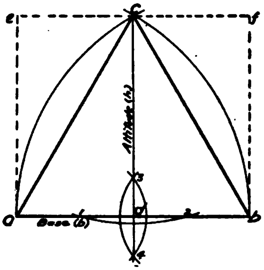

FIGURE 33.

The Formula is: $cd = \sqrt{(ac)^2 - (ad)^2}$

or

The altitude of an equilateral triangle is equal to one-half the product of the side times the square root of 3. $\sqrt{3} = 1.732$

Formula: $altitude = \frac{s\sqrt{3}}{2}$

The *area* (*a*) of an equilateral triangle is equal to one-half of the product of the base (*b*) multiplied by the altitude (*h*).

Formula: $a = \frac{b \times h}{2}$

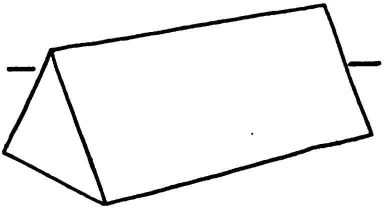

FIGURE 34.

An Equilateral Triangular Prism is one whose bases are parallel equilateral triangles and whose three lateral faces are rectangles.

Its cubical contents are found by multiplying the area of its base by the length or height.

Drawing Problem 10. Make a working drawing of three views and develop the surface of an equilateral triangular prism (Figure 34) with bases which measure 2″ on each side, the length of the prism being 4¼″.

EXAMPLES. 1. What is the surface area of this prism?

2. What is the altitude of the triangular end?

3. How many cubic inches in the prism?

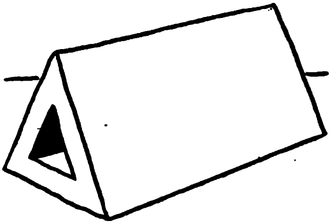

FIGURE 35.

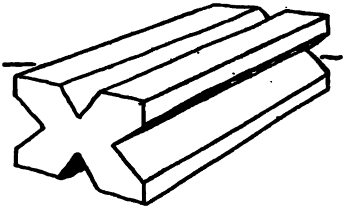

FIGURE 36.

Drawing Problems 11. Make a working drawing of three views of the hollow prism shown in Figure 35. One of the outside rectangular faces measures 7¼″ × 3″. The shell is ½″ thick. Calculate the weight if made of aluminum weighing 159.6 lbs. per cubic foot.

12. Make a working drawing of the V block, Figure 36. The outside dimensions of the block are 6½″ × 4½″ × 3¼″. The V grooves are equilateral triangles, the side of the V cut in the larger faces being 1⅛″ and in the smaller faces 1⅝″. Calculate the number of cubic inches in the block.

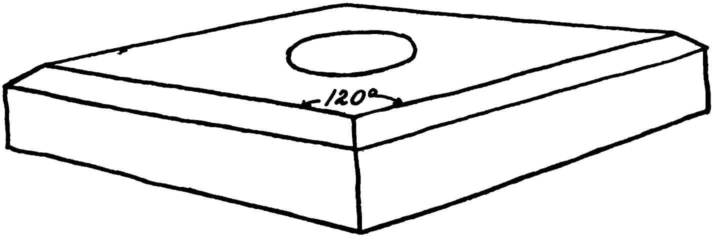

FIGURE 37.

13. Make a drawing of the block shown in Figure 37. A line drawn making the shortest diagonal would show that the outline of the upper face would equal two equilateral triangles. The greatest length is 7½″. The thickness is 1¼″. The diameter of the hole through the block is 1½″. The corners of the upper face are chamfered at an angle of 45°. Calculate number of cubic inches in block.

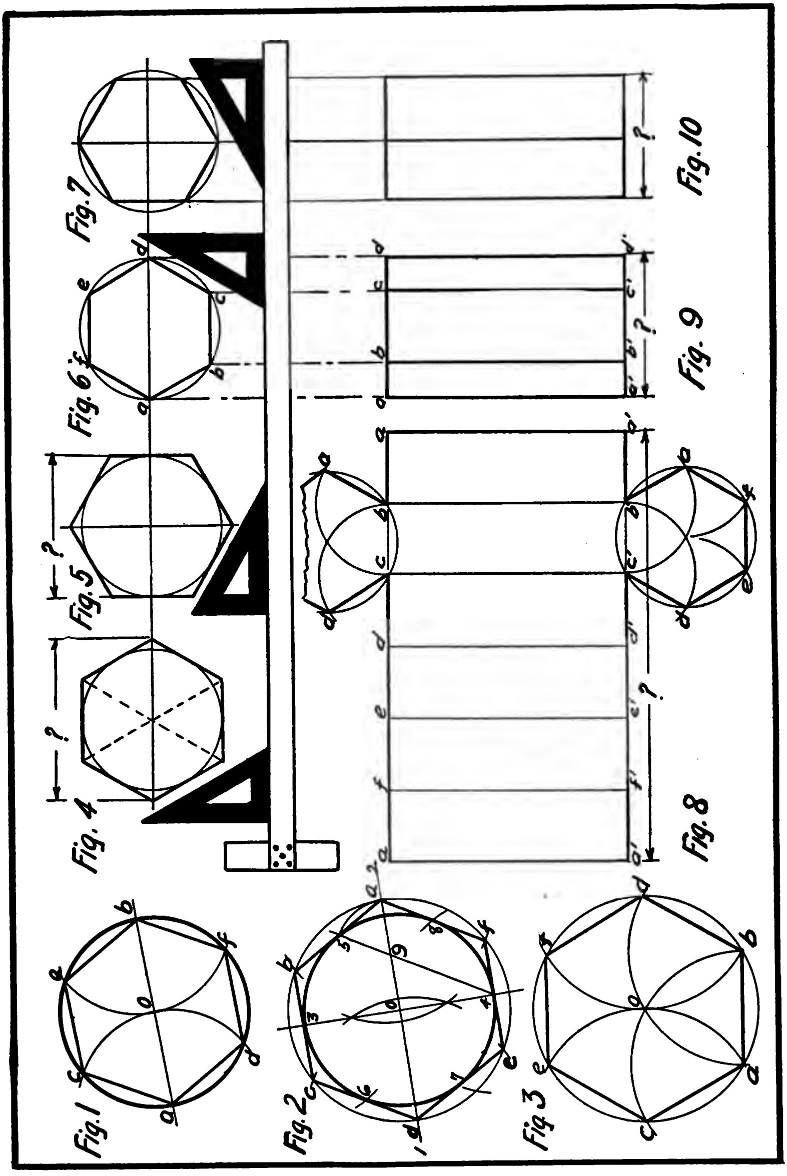

Fig. 1
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Fig. 2
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Fig. 3
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Fig. 6
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Fig. 9
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Fig. 10
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PLATE IX.

The Hexagon and Hexagonal Prism. PLATE IX. The *Hexagon* is a plane figure having six sides equal in length and six equal included angles of 120° each.

GEOMETRICAL CONSTRUCTIONS.

FIGURE 1. When the length of the diagonal *ab*, or the diameter of a circumscribing circle, is given.

Draw the circle with the middle point *o* as a center and radius equal to one-half the length of the line. Then from both *a* and *b* as centers and same radius, draw arcs, giving *cd* and *ef* on the circle. Connect *ac*, *ce*, *eb*, *bf*, *fd*, and *da*.

FIGURE 2. When the distance between parallel sides, or the diameter of the inscribed circle, is given.

Draw any diameter as *1-2* and the bisector *3-4* giving *o*. With *3* and *4* as centers and radius *3-o* draw arcs giving *5*, *6*, *7*, and *8*. Draw line *4-5* giving *9* on *o-2*. With *9* as center and radius *9-5* draw arc giving *a* on line *1-2*. With *o* as center and radius *oa* draw circle through *a* giving *d* on line *1-2*. With both *a* and *d* as centers and radius *ao* draw arcs cutting outside circle at *b*, *f*, *c*, and *e*. Draw straight lines *a5b*, *b3c*, *c6d*, *d7e*, *e4f*, and *f8a*.

FIGURE 3. When the length of one side, *ab*, is given.

With *a* and *b* as centers and *ab* as radius, draw arcs intersecting at *o*. With *o* as center and same radius, draw circle through *a* and *b* giving *c* and *d*. With *c* and *d* as centers and same radius draw arcs *aoe* and *bof*. Connect *bd*, *df*, *fe*, *ec*, and *ca*.

Figures 4, 5, 6, and 7 illustrate methods of constructing the hexagon by using the T square and 30°/60° triangle in connection with the circle.

The Area of any plane figure may be found by dividing it into triangles, quadrilaterals, circles or parts of circles, finding the area of each part separately and adding these results:

The *Area* of the hexagon may be determined by drawing the diagonals as in Figure 4, obtaining six equilateral triangles. The area of the hexagon will be six times the area of one triangle.

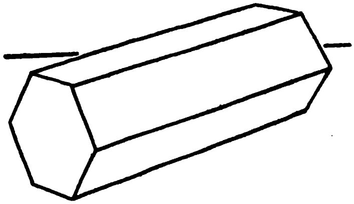

FIGURE 38.

A Hexagonal Prism is one whose bases are parallel equal hexagons and whose other six lateral faces are rectangles. Its cubic contents may be found by multiplying the area of its base by its height. Figures 6 and 9 are the top and front views of a hexagonal prism when two lateral faces are parallel to the vertical plane and Figures 7 and 10 are the top and front views when two lateral faces are perpendicular to the vertical plane. Figure 8 represents the developed surface of the prism.

◆

Drawing Problems. GEOMETRICAL CONSTRUCTION.

14. On a given diagonal, 2¼″ long, construct a hexagon.

15. Circumscribe a hexagon about a circle which is 2¼″ diameter.

16. On a given side, 1¼″ long, construct a hexagon.

WITH T SQUARE AND TRIANGLE CONSTRUCT

17. A hexagon which measures 1½″ between parallel sides.

18. A hexagon which measures 1¾″ across corners.

19. Make a working drawing of three views and develop the surface of a hexagonal prism which measures 1½″ across corners and 2½″ long. Develop surface and calculate entire area of the surface of prism.

20. Make a working drawing showing three views of the nut shown in Figure 39. It is $4\frac{3}{4}''$ between parallel sides and $1\frac{3}{4}''$ thick. The hole through the nut is $3\frac{3}{4}''$ diameter. Calculate the weight if made of brass weighing 523.4 lbs. per cubic foot.

21. Make a working drawing showing three views of the sleeve shown in Figure 40. The hexagonal part is one-third the length of the sleeve, the total length of the sleeve being twice the diameter of the round part, the diameter of which is twice the diameter of the hole through the sleeve. The distance between the parallel sides of the hexagonal part is $3\frac{3}{8}''$, which is two and one-fourth times the diameter of the hole through the sleeve. What will this sleeve weigh if made of brass?

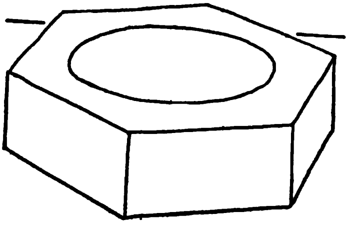

FIGURE 39.

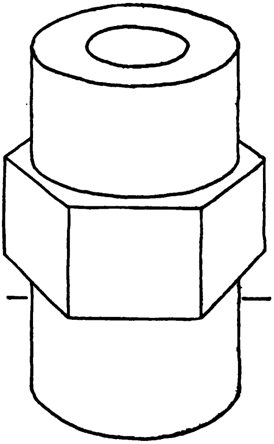

FIGURE 40.

NOTES ON PROJECTION OF LINES

It is often necessary when making a mechanical drawing of some particular construction, to represent an object, or a part of an object, by lines which are not parallel with either the horizontal or vertical planes. When a line is not parallel with a plane its view on that plane can not be represented at its full length as it would appear more or less foreshortened, depending on the angle that the line actually makes with the plane.

It is therefore evident that the art of mechanical drawing must include a method of correctly representing such lines and also of determining their exact measurements and location in space. These methods are to be found involved in the principles of *Orthographic Projection Drawing*, which is the science and art of producing drawings which shall represent completely all facts concerning the position, form and magnitude of all geometric quantities in space.

Only those principles of this science which relate directly to the measurement of lines and their representation on the horizontal and vertical planes, are to be considered at this time. Further application of the principles of *Orthographic Projection* may be found in the study of *Descriptive Geometry* of which science these principles are the basis.

The Planes. When two planes, known as the HORIZONTAL (H) plane and the VERTICAL (V) plane, intersect at right angles as in Figure 41, they form four right angles which are called respectively the *first*, *second*, *third* and *fourth* angles of projection. The dividing line at the intersection of the planes is called the *ground line*.

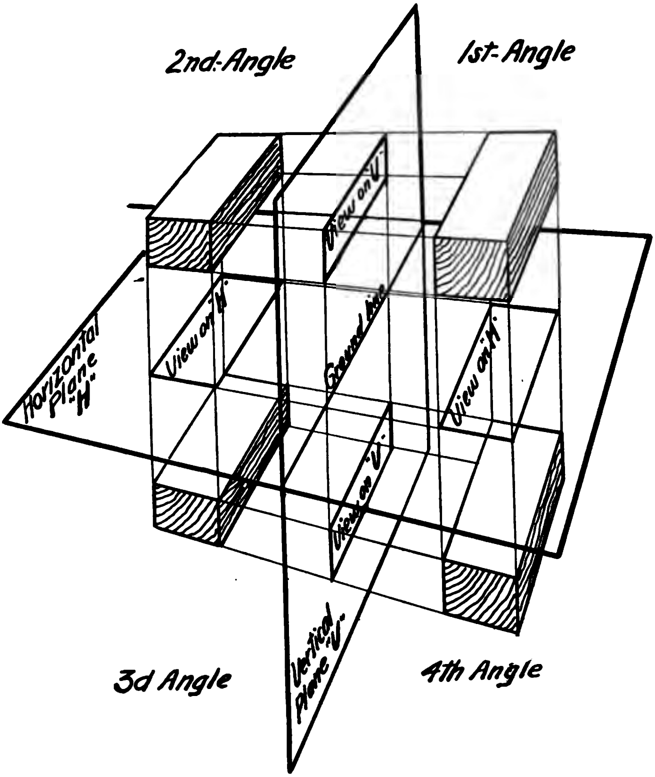

FIGURE 41.

A *point*, *line*, *surface* or *solid* is said to be in the

FIRST ANGLE,	when located above *H* and in front of *V*,
SECOND ANGLE,	when located above *H* and behind *V*,
THIRD ANGLE,	when located below *H* and behind *V*,
FOURTH ANGLE,	when located below *H* and in front of *V*.

These positions are all indicated in Figure 41.

The *third angle* is the one commonly used by draftsmen for it affords the best arrangement of views or projections and this angle is represented by interposing the planes as in Figure 5, Page 22.

Views. The projections of an object on *H* and *V* are called, respectively, the *Horizontal* and *Vertical projections*, or *Plan* and *Elevation*, or *Top view* and *Front view*. Of these three pairs of terms, Top view and Front view are to be preferred. They are more definite and are more consistent with *Bottom view*, *Side view*, or *Rear view*, terms commonly used in regard to working drawings when the corresponding views of the object are represented. As the projection lines which determine any one view of an object on the plane are perpendicular to the plane, they must always be represented by parallel lines.

The Drawing. To represent the planes of projection, a horizontal line is drawn to represent the ground line. That portion of the paper above the line represents the *H* plane and that portion below the line represents the *V* plane as in Figure 42.

Note carefully that the *H* plane is to be always considered first as being at right angles to the *V* plane and lying behind the ground line, then being revolved about the ground line as an axis, into a position above the vertical plane, for convenience in making the drawing of two views of the object on the flat plane of the drawing paper. Therefore the relative position of the different views, or projections, with respect to the ground line and to each other, must be the same as they would appear if the drawing paper were folded at the ground line and placed above and in front of the object.

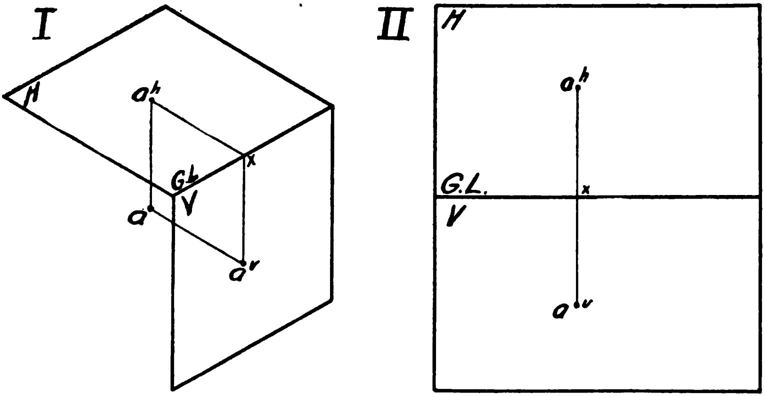

FIGURE 42.

Principles of Projection.

1. A POINT IN SPACE. (Figure 42.)

(a) Every point has two views, one on H and one on V, by which its position in space is determined.

(b) A point and its two views lie in the same plane perpendicular to both H and V,—i.e., a plane passed through the two projection lines. (As the plane a, a^v, a^h, and x, Figure 42.)

(c) The top view of a point is as far behind the ground line as the point itself is behind V. The front view of a point is as far below the ground line as the point itself is below H.

(d) When a point lies in either plane, one of its views coincides with the point itself, the other view being in the ground line.

In the drawing

(e) A point may be represented by its two views, neither of which is the point itself.

(f) The two views of a point always lie in the same straight line at right angles to the ground line.

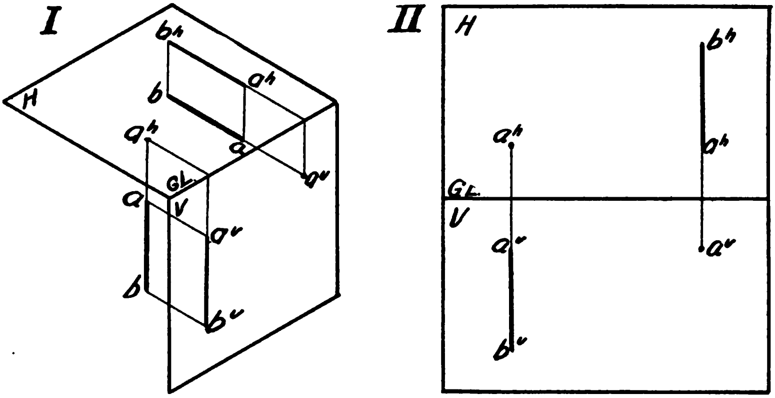

FIGURE 43.

2. A LINE IN SPACE. *Straight lines perpendicular to either H or V.* (Figure 43.)

(a) A line perpendicular to either plane of projection has for its view on that plane simply a point.

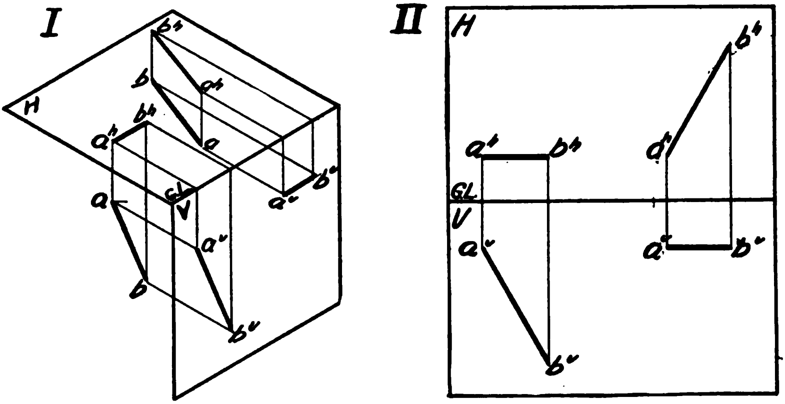

FIGURE 44.

(b) A line perpendicular to either plane, has for its view on the other plane, a straight line perpendicular to the ground line and equal in length to the line in space of which it is the projection.

Straight lines parallel with one plane but at an angle to the other. (Figure 44.)

(c) When a line is parallel with either plane, its view on that plane is equal to the true length of the line in space of which it is the projection; the angle which this view makes with the ground line is equal to the angle which the line in space makes with the plane with which it is not parallel.

(d) A line parallel with either plane of projection has for its view on the other plane a line parallel with the ground line.

(e) When a line is not parallel with a plane its view on that plane is always shorter than the true length of the line in space.

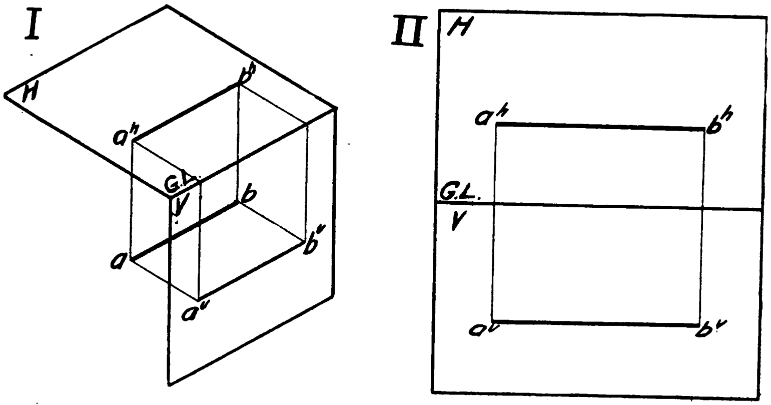

FIGURE 45.

Straight lines parallel with both planes. (Figure 45.)

A line parallel with both planes has for its two views, nes parallel with the ground line, both of which are equal length to the line itself.

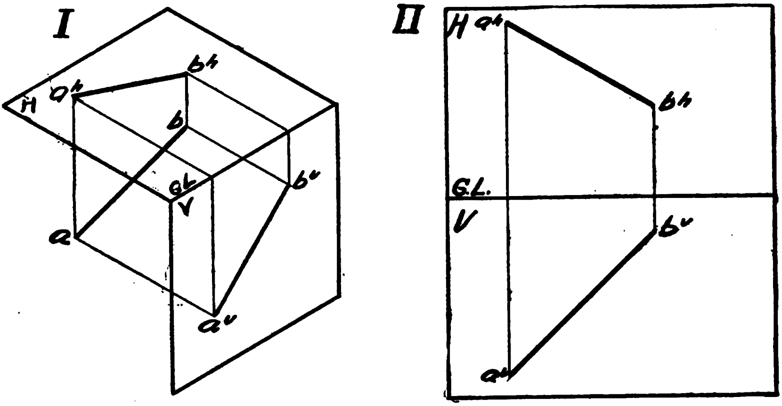

FIGURE 46.

Straight lines parallel with neither plane. (Figure 46.)

If a line is parallel with neither plane, both views are shorter than the line in space. The angles which the line makes to the planes are not represented in their true size by the angles which the views make to the ground line.

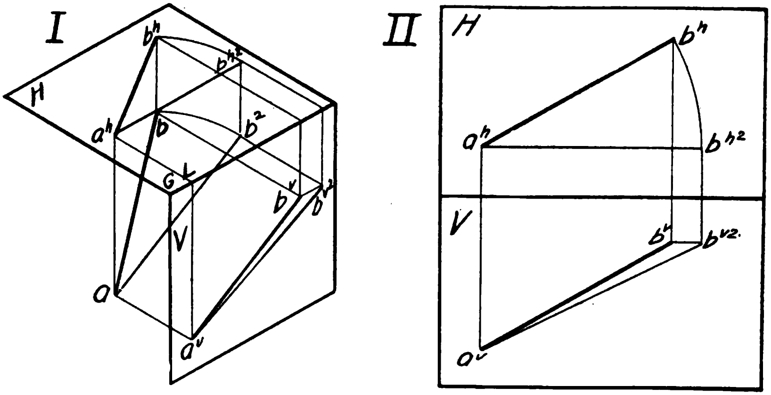

FIGURE 47.

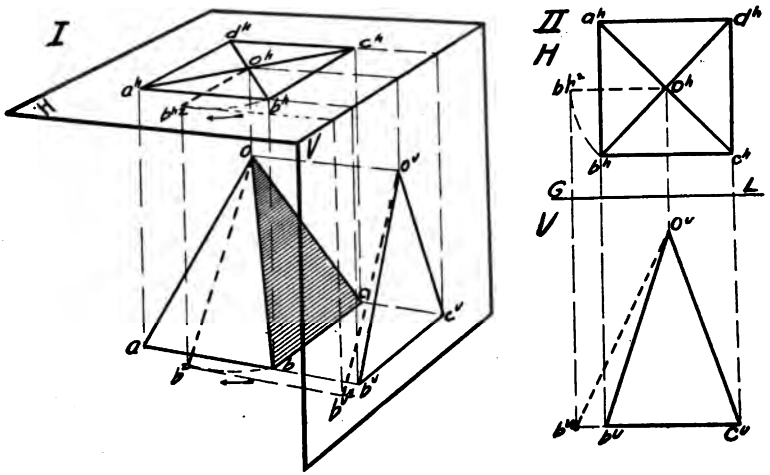

FIGURE 48.

The apparent projection of a line is its appearance on either plane of projection.

By careful consideration of the foregoing principles it becomes evident that it is impossible to obtain the exact length and position of such a line in space as that represented by the two views in *II* of Figure 46, from these views as they appear on the planes, but that it is possible to measure a line on the planes if one of the views shows that the line is parallel with one of the planes. For instance, if the line *ab* is revolved about *a* as a center until its top view becomes parallel with the ground line as a^h, b^{h2}, then its view on *V* will represent the exact length of the line according to principle "*d*" on page 63. This operation is illustrated in *I* of Figure 47 and the method of obtaining this esult in the drawing is illustrated at *II* of the same figure. igure 48 demonstrates the necessity for this operation n determining the length of the line *ob* of the square pyranid, for in neither view is the line shown parallel with the lane on which it is represented.

Problems involving the representation of the apparent location of lines in space.

1. Represent
    - (a) A line 1¾″ long, perpendicular to *H*, ½″ from *V*, top end ¼″ below *H*.
    - (b) A line 1½″ long, perpendicular to *V*, ¾″ from *H*, nearest end ¼″ behind *V*.
    - (c) A line 1½″ long, parallel with both *H* and *V*, and 1″ from both planes.
    - (d) A line 1¾″ long, parallel with *V*, slanting downward to the right at 30° to *H*, ¾″ behind *V* and the top end ¼″ below *H*.
    - (e) A line 1½″ long, parallel with *H*, slanting back toward the right at 60° from *V*, nearest end is ½″ from *V* and the line is 1″ below *H*.

2. Represent the apparent projection in *V* of a line which is 2″ long placed at 45° to *H* and whose top view shows that it makes an angle of 45° with *V*. Its top end is ½″ from both *H* and *V*. The line slants downward and backward to the right.

3. A line appears 2¼″ long at apparent angles of 45° to both *H* and *V*. Its top end is ¼″ below *H* and 2″ behind *V*. The line slants downward and forward to the right. Determine its true length and exact angles that the line makes with both *H* and *V*.

4. A line slanting downward, forward, and to the left appears to be 2¼″ long at 60° to *H*. Its top view appears at 45° to *V*. The top end is ¼″ below *H* and 1¾″ behind *V*. Determine the true length and actual position of the line in space.

5. A side view or profile projection of a line shows it placed at 60° to *H* and 30° to *V*. The line is 1¾″ long and its top end is ½″ from *H* and 1½″ from *V*. The line slants down toward *V*, and is 1″ behind the profile plane. Make the *H* and *V* projections of the line.

Draw H and V projections.

6. (a) Of a card, 2½″ square, surface perpendicular to *H*, parallel with and ¾″ behind *V*. The top edge is 1¾″ below *H*.

(b) Of the same card with the front face turned toward the right at 45° to *V*.

(c) Of the same card when besides being turned at 45° to *V* the edges which were parallel with *H* make an apparent angle of 45° to *H* in the front view. The card is tipped toward the right.

7. (a) Of an equilateral triangular card, sides 2¼″ long, surface parallel with *H* and front edge parallel with *V*. The card is 1½″ below *H* and the front edge is ½″ behind *V*.

(b) Of the same card when its front edge slants down to the right at 30° to *H*.

(c) Of the same card when its front edge besides slanting down to the right at 30° to *H* is turned back toward the right in the top view at 45° to *V*.

8. (a) Of a cube with faces 2″ square, having its top front edge parallel with both *H* and *V*, 1½″ below *H* and ½″ behind *V*.

(b) Of the same cube with its front face parallel with *V* and its top face at 30° to *H*. Cube tipped over toward the right.

(c) Of the same cube when besides having its top face at 30° to *H*, has its front face turned back toward the left at 30° to *V*.

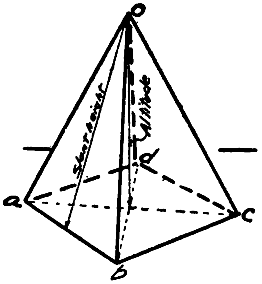

FIGURE 49.

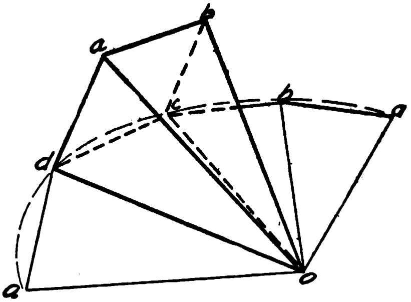

FIGURE 50.

The Square Pyramid. PLATE X.

Drawing Problem 22. Make top and front views of a pyramid (Figure 49) having a base $2\frac{1}{4}''$ square and an altitude of $3\frac{1}{2}''$. Develop surface and calculate surface area of the pyramid.

If a square pyramid should be laid down on one of its triangular faces, and the outline of that face traced; the pyramid then rolled over, using one of its slant edges as an axis, and the adjacent face traced; continuing the operation until all the faces were traced; the result would be the surface layout or development of the triangular faces of the pyramid, as illustrated in Figure 50. The points, *a*, *b*, *c*, *d*, *a*, of this development are all equidistant from the point *o*. An arc with *o* as a center and *oa* as a radius would pass through each point. To develop the surface of a pyramid, draw an arc using the *exact length* of one of the *slant edges* of the pyramid as a radius. This exact length may be found by projection as illustrated in Figure 48 or it may be calculated by determining the length of the hypotenuse of the right-angled triangle which has for the length of one of its two sides the altitude of the pyramid, and for the other side one half the length of the diagonal of the base.

The surface area of any regular pyramid is equal to the area of the base plus the area of all of the triangular faces. It may be determined by multiplying the perimeter of the base by one-half the slant height and adding the area of the base.

The *slant height* is the length of a line drawn perpendicular to the side of the base from the vertex of the pyramid.

The volume of a pyramid is equal to the area of the base multiplied by one-third of the altitude.

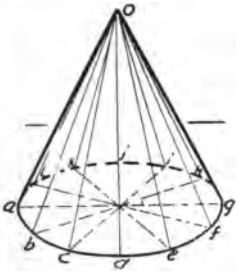

FIGURE 51.

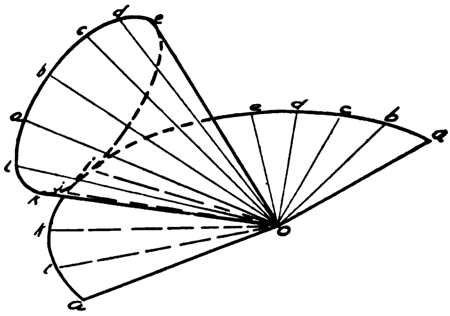

FIGURE 52.

The Cone. A *circular cone* is a round body whose base is a circle and whose convex surface tapers uniformly to a point called the vertex. A right circular cone is a circular cone having its axis perpendicular to its base and this cone may be generated by the revolution of a right-angled triangle about one of its sides as an axis. (Figure 51.)

Drawing Problem 23. Make top and front views of a cone having a base 3¼″ diameter, and an altitude of 3¾″. Develop surface and calculate surface area of the cone.

For convenience in developing the surface a number of working lines called *elements* may be drawn from the vertex of the cone to the base. These are usually spaced equidistant as shown in the top view of the cone Plate X. By drawing an arc with a radius equal to the exact slant height of the cone and spacing off on this arc the same number of divisions equal in length to those on the circumference of the base, the surface development of the cone may be laid out. This operation is suggested in Figure 52 and represented in Figure 4 of Plate X.

The surface area of the right circular cone is equal to the lateral area plus the area of the base. The lateral area is equal to the circumference of the base multiplied by one-half the slant height. The volume of the right circular cone is equal to the area of its base, multiplied by one-third its altitude.

If the upper part of a pyramid or cone is cut off by a plane parallel with the base the remaining lower portion is called the *frustum*.

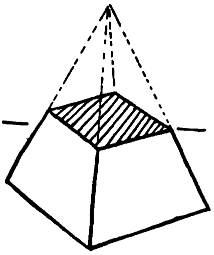

FIGURE 53.

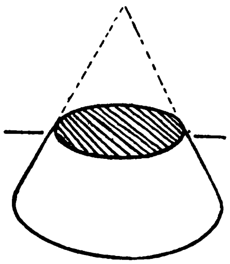

FIGURE 54.

Drawing Problems.

24. Make top and front views and develop the surface of the frustum of a square pyramid. (Figure 53.) The lower base is 3¼″ square, and the upper base is 1¾″ square. The distance between the two bases is 2½″. What would be the altitude of the complete pyramid? Calculate the entire surface area and the volume of the frustum.

25. Make top and front views and develop the surface of the frustum of a cone whose lower base is 5½″ diameter, the upper base 2¾″ diameter, and the distance between the two bases, 2¼″. Determine the altitude of the complete cone and calculate the entire surface area and volume of the frustum. (Figure 54.)

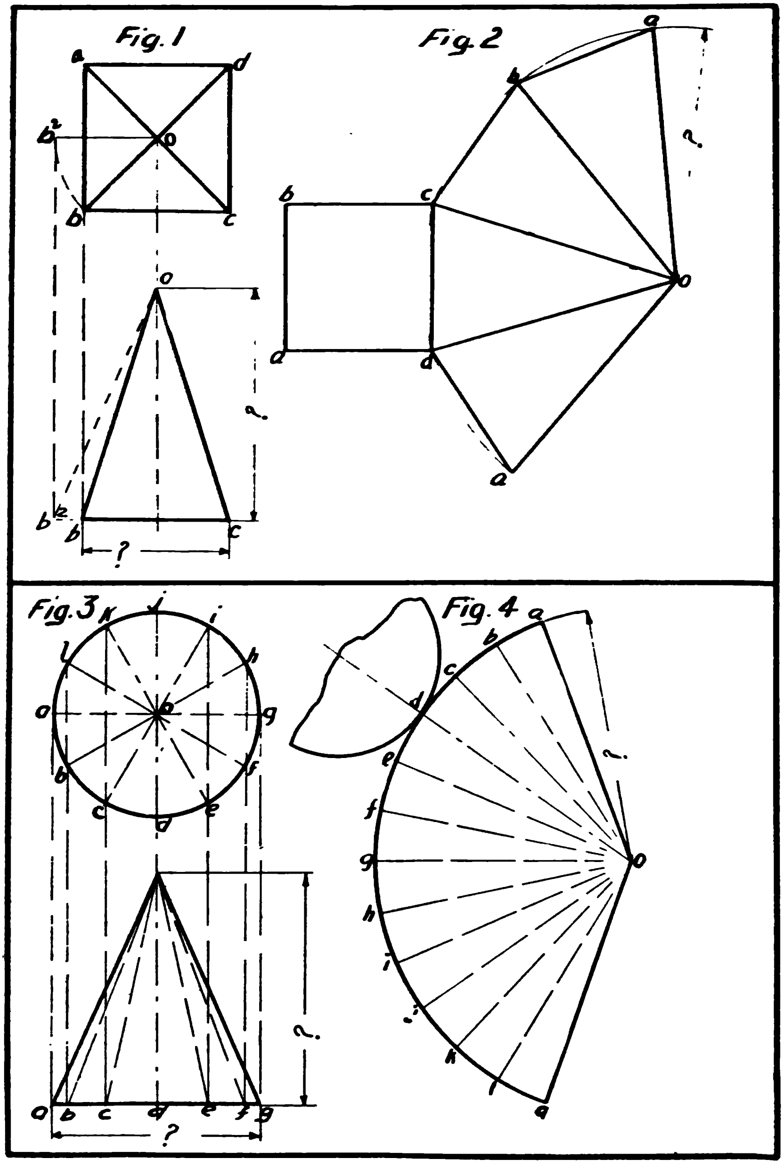
Fig. 1
a
d
b²
o
b
c
o
?
b²
b
c
?
Fig. 2
a
b
c
b
o
a
d
a
?
Fig. 3
k
j
i
l
h
a
o
g
b
f
c
d
e
?
a
b
c
d
e
f
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Fig. 4
a
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Plate X.

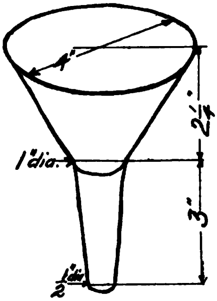


FIGURE 55.

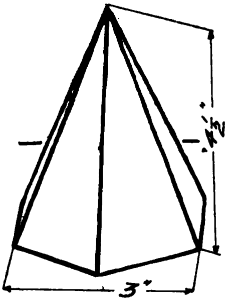


FIGURE 56.

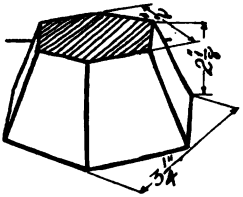


FIGURE 57.

26. Make working drawings, lay out surface pattern and calculate surface area of the funnel illustrated in Figure 55.

27. Make front and top views of the hexagonal pyramid following dimensions given in Figure 56. Lay out and calculate surface area and volume of the pyramid.

28. Make top and front views of the frustum of the hexagonal pyramid following dimensions given in Figure 57. Lay out and calculate surface area and volume of frustum.

AUXILIARY VIEWS

Sometimes an object is placed in such a position that the usual top, front and side views do not adequately represent the actual shape of certain parts of the object. This fact is illustrated in Figure 58 where neither view represents the actual size and correct outline of that part of the cube remaining after a portion of the cube has been cut away. It

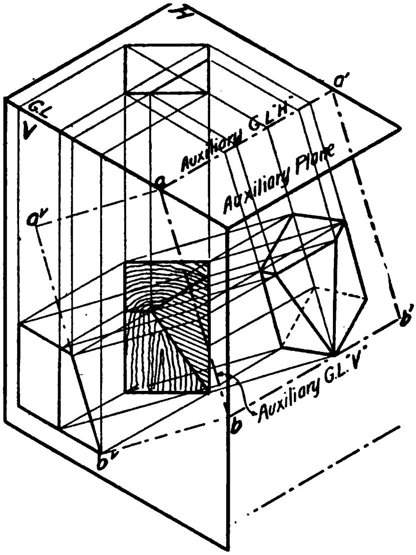


FIGURE 58.

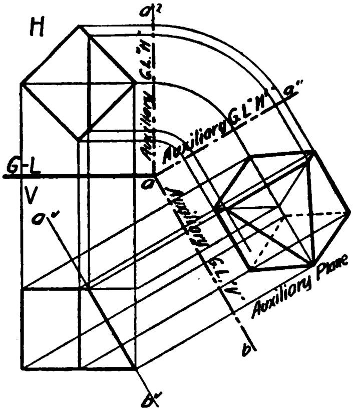


FIGURE 59. FIGURE 60.

is therefore necessary to make another projection on a plane known as an "*auxiliary plane.*" The auxiliary plane is always placed parallel with the surface to be represented, as in Figure 58, where the dot and dash lines *a-b*, *b-b'*, *b'-a'*, *a'-a*, represent the edges of such a plane. In this case the auxiliary plane is perpendicular to the *V* plane and at the same angle to the *H* plane as the line a^v-b^v, which cuts the *V* projection of the object. By projecting parallel lines, from every point of the object perpendicular to the auxiliary plane, the resulting projection on that plane will represent the exact size and shape of the part required and a forehortened view of the remaining portion of the object. Figure 60 illustrates the application of the auxiliary plane in epresenting the object on the flat surface of the drawing paper. The *H* projection represents the top view of the cube when it is placed with its vertical faces at 45° to *V*. The front view of the cube is cut by a line, a^v-b^v, representing the edge of a cutting plane which cuts away a portion of the cube at a certain angle to *H* and perpendicular to *V*. The line *a-b*, parallel with a^v-b^v, is the *G. L.* "*V*" of the auxiliary plane and *a-a'*; perpendicular to *a-b*, is the auxiliary *G. L.* "H^1" revolved into this position from the position indicated by *a-a'*. The three planes are thus shown revolved into the one flat plane of the drawing paper. Parallel projection lines perpendicular to the cutting line a^v-b^v, are projected from every point in the front view into the auxiliary plane. Lines parallel with *G. L.* are projected from the points in the top view to the auxiliary *G. L.* "*H*" and then revolved, by drawing arcs with *a* as a center, to the *G. L.* "H^2" from which they are projected into the auxiliary plane. At the intersections of the projection lines from corresponding points in the *H* and *V* projections are the same points in the view on the auxiliary plane. The view on an auxiliary plane is known as a "*revolved view.*"

When making revolved views, it is not always necessary to indicate the positions of the imaginary ground lines dividing the paper into the three planes. The center line of a revolved view must always be placed parallel with the edge of the cutting plane as represented in the plane to which the cutting plane is perpendicular. Measurements for the revolved view may be made from the view which does not contain the edge of the cutting plane. Such measurements must always be made in a direction perpendicular to the imaginary ground line between the *H* and *V* projections.

Drawing Problem 29. Make top, front and revolved views of the object represented in Figure 61, also laying out a surface pattern of the object as indicated in the illustration. The object is 1½"×2¼"×3". In the front view, the upper right-hand corner is cut off by a plane which is perpendicular to *V* and at 45° to *H*. The distance from *a* to *b* is ½".

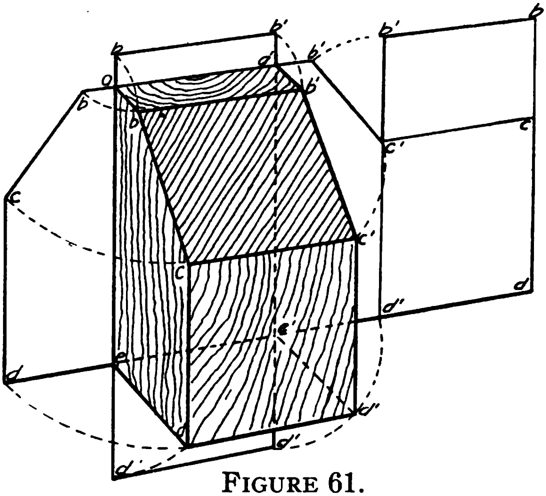


FIGURE 61.

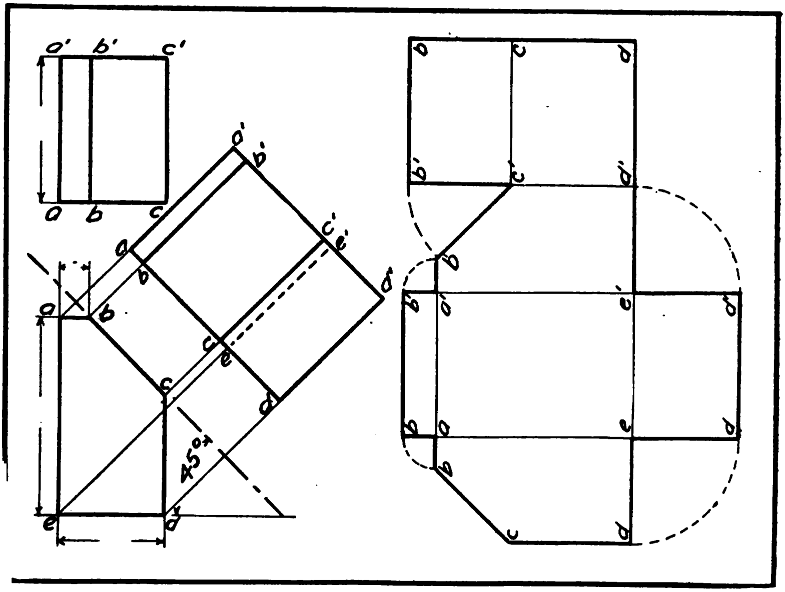


FIGURE 62.

The three views and the developed surface pattern required in this problem are given in Figure 62. The edges of the surfaces *a b c d e a* and *a′ b′ c′ d′ e′ a′* appear in the revolved plane as lines parallel with the edge of the cutting plane represented in the front view. The surface *bb′ c′ cb* in the revolved view is the exact size of that particular portion of the surface of the object. Measurements for the developed surface pattern are all obtained from the three views of the object.

Drawing Problems.

30. Make top, front and revolved views, also lay out surface pattern of the cube illustrated in Figure 59. The square faces of the cube each contain 2¼ square inches, and the vertical faces are placed at 45° to *V*. The cutting plane is at 60° to *H* and perpendicular to *V*, and passes through the lower right-hand corner of the front view of the cube. How many square inches of material in the surface pattern of the remaining portion of the cube?

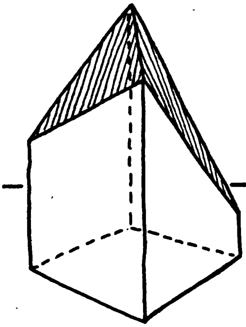


FIGURE 63.

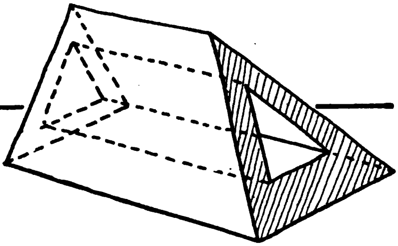


FIGURE 64.

31. Represent a square prism which measures 1¼″×1¼″×4″, resting on one of its bases with its vertical sides at 45° to *V*. Then cut away the upper right-hand corner in the front view by a plane passing through the center of the

top of the prism, perpendicular to *V* and at 60° to *H*. Cut away the upper left-hand corner in the front view by a plane passing through the center of the top of the prism and which is at 30° to *H* and perpendicular to *V*. Lay out the developed surface pattern without making the revolved views to show the exact outline of the portions left after cutting the prism. (Figure 63.)

32. Represent the top, front and end views of a hollow equilateral triangular prism with one end cut away as in Figure 64 by a plane which is at 45° to *H* and perpendicular to *V*. The lower rectangular face of the prism is 4″×2″ and its sides are $\frac{3}{8}$″ thick. Develop surface and calculate area of surface pattern.

33. Plate XI. A cylinder, 1$\frac{3}{4}$″ diameter and 3″ high, is cut by a plane at 45° to *H* and perpendicular to *V*. Represent the front, top, side and revolved views. The side view is to be located on the center-line *S* indicated in Plate XI.

34. Make top and front views of a cylinder, 2″ diameter and 3$\frac{1}{2}$″ high, cut in the front view by a line representing the edge of a plane perpendicular to *V*, passing through the upper left-hand and the lower right-hand corners of this view. Make revolved view showing the exact shape of the remaining portion left by the cutting plane and also lay out the surface pattern of the cylinder by the method shown in Plate XI.

In making revolved views and developed surfaces of cylindrical objects it is necessary to assume a considerable number of points on the cylindrical surface to assist in making the required projections. If the circle representing the end or top view of the bases of the cylinder be equally divided by drawing a number of diameters as in Figure 2 of Plate XI and then projection lines drawn from the points where these diameters cut the circumference, through the front view (Figure 3), points are obtained which aid in making the required projections. These lines crossing the cylindrical surface are called *elements* and the greater the number of these elements used the more accurate will be the result in

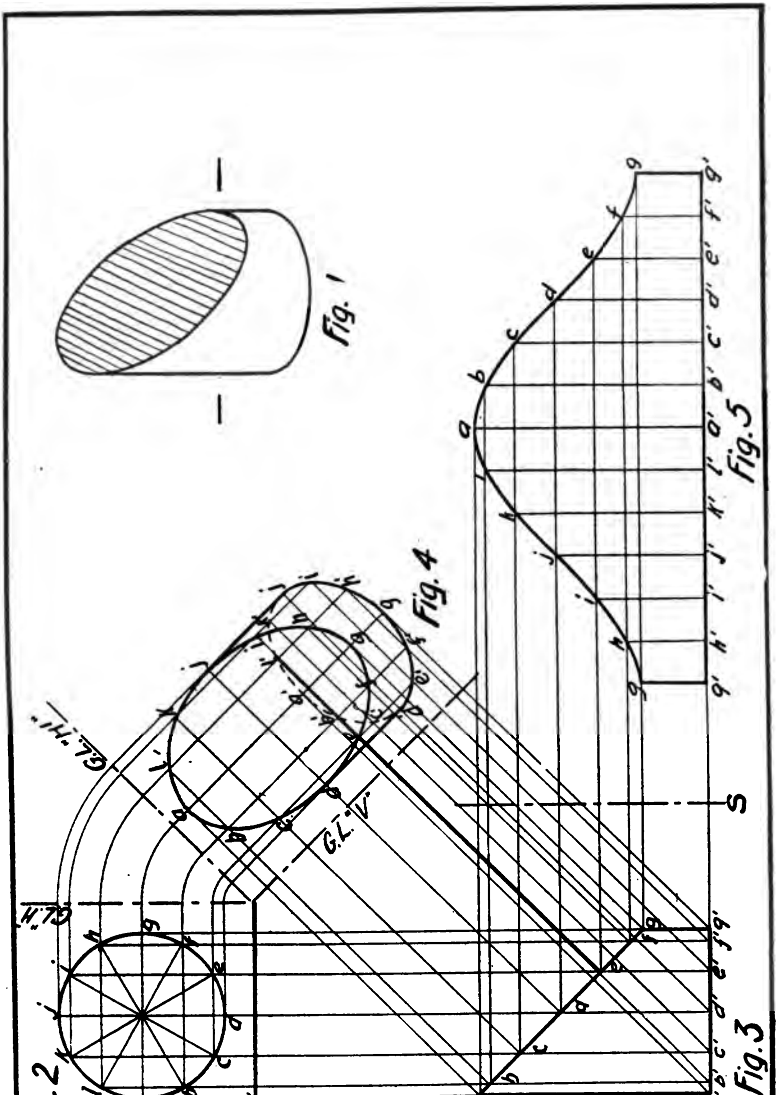


Fig. 1
Fig. 2
Fig. 3
Fig. 4
Fig. 5
G.L.
H.T.D.
G.L.H.
G.L.V.
S
a b c d e f g h i j k l
a' b' c' d' e' f' g' h' i' j' k' l'

PLATE XI.

the drawing. Usually *twelve* to *twenty-four* elements are employed as it is convenient to divide the circle into these numbers of parts by using the T square and the triangles.

In both problems 33 and 34, the cutting plane intersects all of the elements in the front view. (Figure 3.) By using all of these intersections as points from which to draw projection lines, the revolved view is obtained as indicated in Figure 4.

To obtain the developed surface (Figure 5) draw first the line g'-g' equal in length to the circumference of the cylinder and space for the positions of the vertical lines representing the elements. The length of the elements may be determined by measurement or by projection as indicated in the drawing. A line passing through the intersections of the projection lines with the elements gives the required outline for the surface pattern.

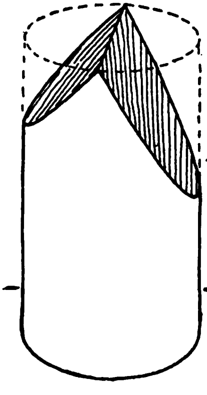


FIGURE 65.

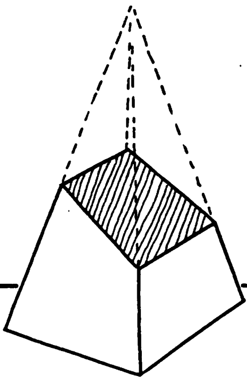


FIGURE 66.

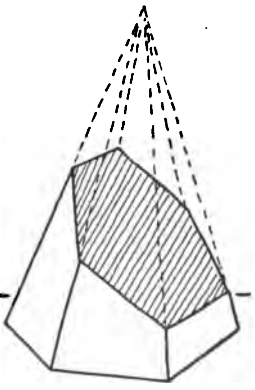


FIGURE 67.

Drawing Problems.

35. Represent top and front views of a cylinder $1\frac{3}{4}''$ diameter and $3\frac{3}{4}''$ high. Cut away the upper left-hand corner as far as the center of the top in the front view by a plane at 45° to H and perpendicular to V. Cut away the upper right-

hand corner as far as the center of the top in the front view by a plane at 60° to *H* and perpendicular to *V*. Make revolved views of only the cut portions, not representing the foreshortened views of the rest of the cylinder. Make surface development. (Figure 65.)

36. Represent a hexagonal prism resting on one of its bases and with two lateral faces parallel with *V*. The bases are $1\frac{1}{2}''$ between parallel sides and the lateral faces are $3\frac{1}{4}''$ high. Cut the prism in the front view by a plane passing through the upper left-hand corner at 60° to *H* and perpendicular to *V*. Make revolved view and develop surface.

37. Represent a square pyramid with two sides of its base perpendicular to *V*. The base is $2\frac{1}{4}''$ square and the altitude of the pyramid is $3\frac{1}{8}''$. Cut the pyramid by a plane which is at 30° to *H*, perpendicular to *V*, and passes through a point 1″ above the center of the base in the front view. Make revolved view and develop surface. (Figure 66.)

38. Represent the pyramid given in problem 37 with the sides of the base at 45° to *V*, and cut the pyramid at the same distance above the center of the base by the same cutting plane. Make revolved view and develop surface.

39. Make front, top and revolved views of a hexagonal pyramid cut as indicated in Figure 67. Pupil to determine size of pyramid and angle of cutting plane.

Conic Sections. If a right circular cone is cut by planes passing through it in various directions the sections will show several different geometrical figures and curves.

The names of these figures and curves, and the conditions under which they may be obtained are:

1. **The Circle.** Obtained by cutting all the elements of a right circular cone by a plane parallel with the base, passing through the cone at any point above the base.

2. **The Isosceles Triangle.** Obtained by cutting a right circular cone by a plane perpendicular to the base and passing through the axis of the cone.

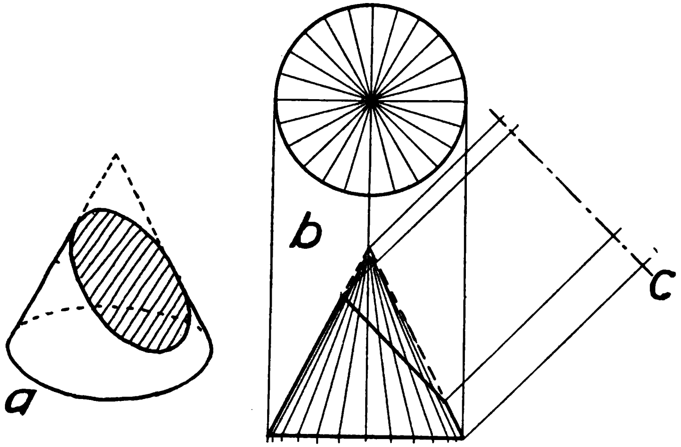


FIGURE 68.

3. **The Ellipse.** Obtained by cutting all the elements of a right circular cone by a plane which passes through the cone at any point above the base at any angle and which is not parallel with any of the elements nor the base of the cone. (Figure 68 *a*.)

4. **The Hyperbola.** Obtained by passing a plane perpendicular to the base, through the right circular cone at any place where the plane will not pass through the axis of the cone. (Figure 69 *a*.)

5. **The Parabola.** Obtained by passing a plane through the base of the cone and parallel with any one of the elements. (Figure 69 *c*.)

Drawing Problems.

40. Make front, top and revolved views of the truncated cone illustrated at *a* in Figure 68. The cone has a base 3″ diameter, and its altitude is 3¾″. It is cut by a plane at 45° to *H* and perpendicular to *V*, through a point 2″ above the center of the base in the front view. Develop the surface of the cone.

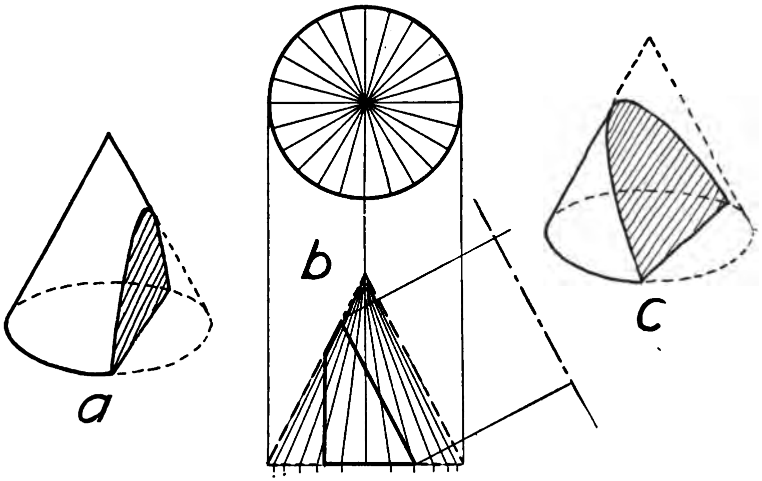


FIGURE 69.

41. Make top, front and side view of a cone of the dimensions given in problem 40. Pass a cutting plane through the plane in such a position that the side view of the remaining portion of the cone will show a *hyperbola.* Lay out surface development.

42. Represent this same cone cut by a plane in such a manner that the revolved view will show a *parabola.* Develop surface.

43. A working drawing is required for a pattern of a 25 *lb. dumb-bell* of the construction represented in Figure 70, and having the dimensions given for the size of the handle and the thickness of the ends. What is the weight of the cross-bar and what should be the weight and diameter of each end? The V grooves are made in the cross-bar in order to secure a retaining hold on the cast-iron ends.

This problem involves the representation of the *Ellipse* and the solid known as the *Spheroid.*

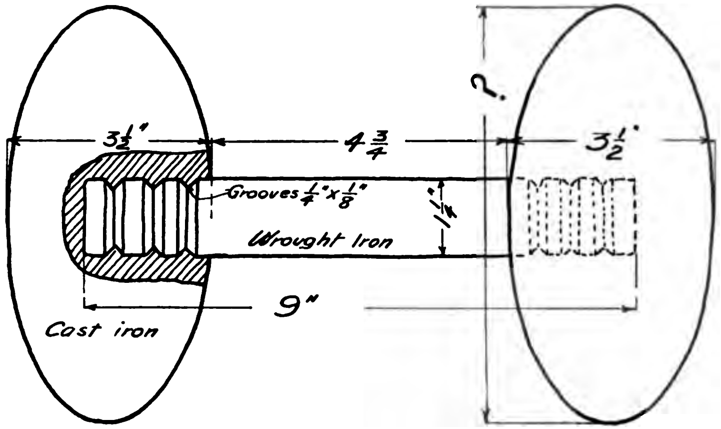


FIGURE 70.

The Ellipse is an oblong figure bounded by a regular curve and corresponds to an oblique view of a circle. (See revolved view of cylinder Plate XI.)

The *long* axis of the ellipse is called the *major* or *transverse* axis. The *short* axis is called the *minor* or *conjugate* axis.

The ellipse is also defined as a curve in which the sum of the distances from any point of the curve to two fixed points (called *foci*) in the major axis is constant. That constant is the length of the major axis.

The minor axis is always perpendicular to the major axis.

TO DRAW THE ELLIPSE:

First method. (Figure 71.) Draw the two axes *ab* and *cd* bisecting each other at *e*. With radius equal to *ae* and *c* and *d* as centers locate the foci *f* and f^1 on the major axis *ab*. The sum of the distances *cf* and cf^1, and also the sum of the distances from *f* and f^1 to any other point in the curve of the

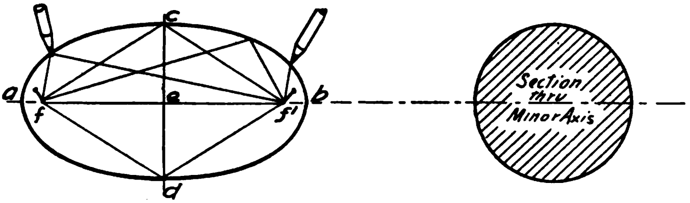


FIGURE 71.

ellipse are equal to the length of the major axis *ab*. Place pins in the axis at *f* and f^1 and loop on an endless thread of such length that when a pencil point is placed within the loop, the loop will allow the pencil to just reach to *c* or *d*. By guiding the pencil with the thread, it may be carried around the pins at *f* and f^1, thus describing the ellipse.

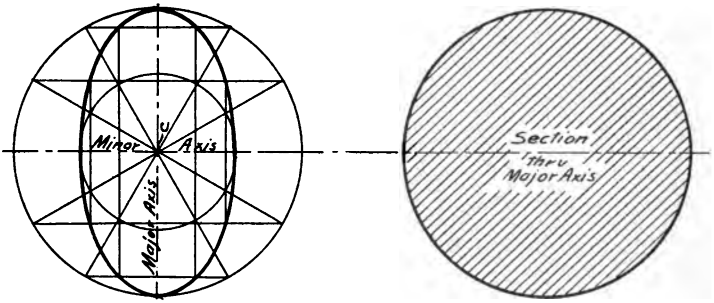


FIGURE 72.

Second method. (Figure 72.) At the intersection of the diameters, *c*, as a center, draw circles equal to the diameters of the required ellipse. From any number of equally spaced points in the circumference of the larger circle draw radii cutting the inner circle. Draw lines perpendicular to the major axis from the points on the outer circle intersecting lines drawn parallel with the major axis through the points on the inner circle. A curved line traced through the points of intersection of the lines is the curve of the ellipse. There are many other methods of constructing the ellipse which may be substituted for those described.

In making calculations for the ellipse, let D equal the length of the major axis and d equal the length of the minor axis.

The *area of an ellipse* is approximately equal to the product of its axes multiplied by *.7854.*

Formula: *area of ellipse*$=D\times d\times .7854$.

The *length of the circumference* may be approximately determined by multiplying the square root of one-half the sum of the squares of the two axes, by *3.1416.*

Formula: *circumference of ellipse*$=3.1416\sqrt{\frac{D^2+d^2}{2}}$

The Spheroid is a solid generated by the revolution of an ellipse about one of its axes. A section cut through the spheroid at any point by a plane parallel with one of its axes is either a circle or an ellipse. It is called a *prolate spheroid* when it is revolved about the major axis (Figure 71) and an *oblate spheroid* when revolved about the minor axis. (Figure 72.)

The *area of the surface* of a spheroid may be approximately determined

when it is prolate by multiplying the area of the revolving ellipse by the length of the minor axis.

Formula: *area of prolate spheroid*$=3.1416\sqrt{\frac{D^2+d^2}{2}}\times d$

when it is oblate by multiplying the area of the revolving ellipse by the length of the major axis.

Formula: *area of oblate spheroid*$=3.1416\sqrt{\frac{D^2+d^2}{2}}\times D$

The *volume of a spheroid* may be approximately determined by multiplying the square of the revolving axis (R) by the fixed axis (F) and the product thus obtained by *.5236*.

Formula: *volume of spheroid* $= R^2 \times F \times .5236$

In order to determine the diameter of the ends of the dumb-bell, it is first necessary to deduct the weight of the bar and this will give the weight to be allowed for both ends. Allowance must be made for the amount of material in that part of the bar cast into the ends, and then the number of cubic inches of cast-iron in each end must be determined. The diameter of the ends may be calculated by applying the formula for finding the volume of the spheroid.

Formula: $R^2 \times F \times .5236 = \text{number of cu. inches in each end}$

$$R^2 = \frac{\text{number of cu. inches in each end}}{F \times .5236}$$

R = *diameter of end or length of revolving axis.*

Questions.

1. How does the ellipse differ from a circle?
2. What are the foci of an ellipse?
3. What special fact is peculiar to the ellipse regarding the sum of the distances of the foci from any point in the circumference of the ellipse?
4. What kind of a spheroid is indicated in the drawing of the dumb-bell?
5. Would it make any difference in the weight if the drawing had indicated the other kind of a spheroid?

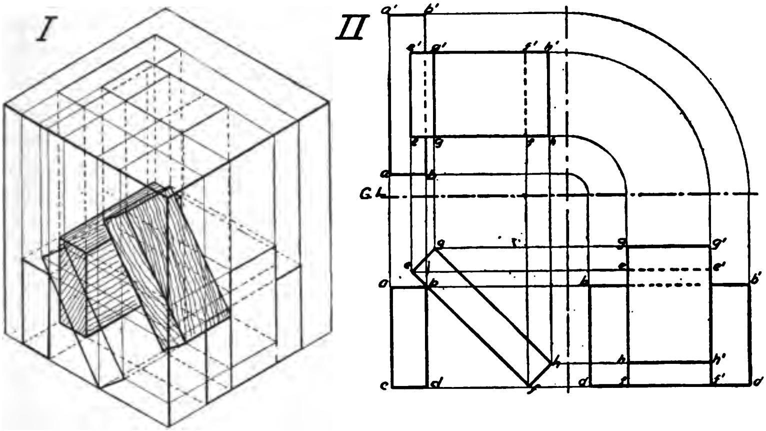


Figure 73.

The Representation of Groups of Solids

All forms of construction may be readily conceived as being composed of groups of type solids assembled together in various ways necessary to obtain the required construction. Examine carefully the drawings of any machine or building and it will be evident that such drawings contain the representations of many plane geometrical figures combined to make the complete drawing.

In making a drawing which shall represent the combination of a number of plane figures or groups of solids, the position and relation of each member of the group in regard to each other must be carefully considered. Each of the views made must show each member of the group in its own particular position in space and its relation to the other members of the group in their relative positions. Figure 73–I illustrates the projections of a group of two solids on the three planes giving the front, top and side views of the group.

The projection of each member of the group is made showing its particular position in space. The relation of the views to each other is readily determined by the projection lines on the surface of the planes. The appearance of each member of the group and its relation to the other member as represented on the flat plane of the drawing paper is clearly illustrated in II of Figure 73 where the three planes have been revolved into the one plane surface of the paper.

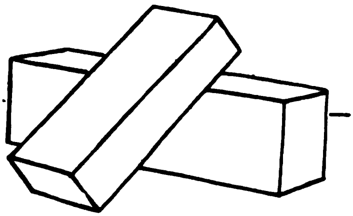


FIGURE 74.

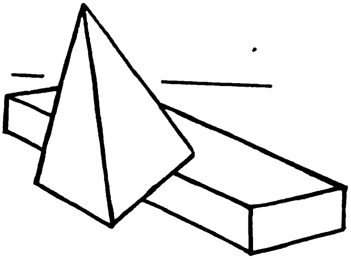


FIGURE 75.

Drawing Problems.

44. Represent the top, front and side views of two rectangular prisms, in the positions suggested in Figure 74. The prisms are each $1\frac{1}{8}'' \times 1\frac{1}{2}''$, the lengths being $3\frac{1}{2}''$ and $4''$. The ends of the longer prism are parallel with *V* and perpendicular to *H*. The shorter prism rests at the center of the top left-hand edge of the other prism and its wider faces make an angle of 30° with *H* and they are perpendicular to *V*.

45. Represent three views of a group consisting of a square pyramid, base $2'' \times 2''$, altitude $2\frac{3}{4}''$, resting as in Figure 75 on a rectangular prism which is $\frac{3}{4}'' \times 1\frac{3}{4}'' \times 3\frac{1}{4}''$. The larger faces of the prism are perpendicular to *V* and parallel with *H*.

The base of the pyramid is perpendicular to *V* and at 30° with *H*, and the pyramid inclines toward the left.

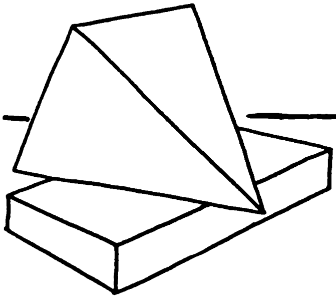


FIGURE 76.

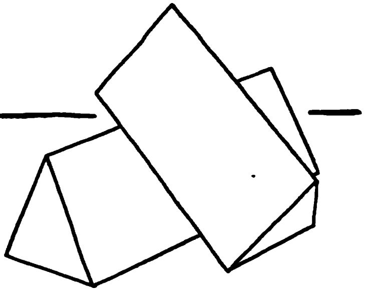


FIGURE 77.

46. Represent three views of the prism and pyramid described in example 45, in the position suggested in Figure 76. The prism is in the same position but the pyramid rests on one of its triangular faces which is now shown as being parallel with *H* and perpendicular to *V*.

47. Represent three views of a group of two equilateral triangular prisms, in each of which the lateral faces are $1\frac{3}{4}'' \times 3\frac{1}{4}''$. The lower face of the upper prism makes an angle of 45° to the lower face of the prism upon which it rests. Both lower faces are perpendicular to *V*. (Figure 77.)

48. A cylinder, 4″ diameter, 1″ thick, is placed with its bases parallel with *V* and perpendicular to *H* as in *A*, Figure 78. It is then turned away with its bases at 45° to *V* as in *B*, Figure 79. Represent top and front views of the cylinder in both positions.

In making this drawing it will be necessary to assume a number of elements in order to obtain working points from which to make the projections for the second front view of the cylinder.

After the top view has been turned to its second position, vertical projection lines are drawn from this view into the *V* plane, intersecting horizontal projection lines from corresponding points in the first front view. The inter-

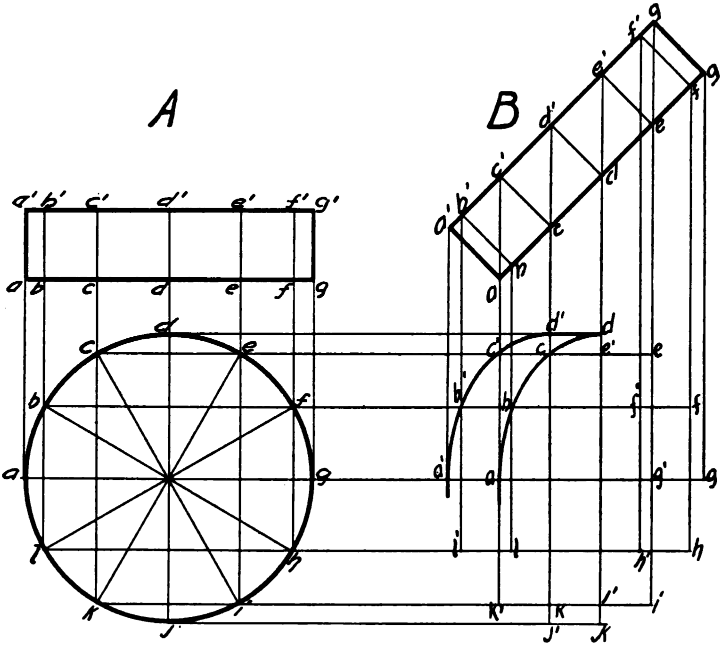


FIGURE 78.

sections of the projection lines give points through which the outlines of the second front view of the cylinder may be traced.

49. Represent front, top and side views of a group consisting of a cylindrical ring and a triangular prism as illustrated in Figure 1 of Plate XIII. The ring is $4\frac{1}{8}''$ diameter and $\frac{7}{8}''$ thick, with the hole $2\frac{3}{4}''$ diameter. One face of the prism is $4\frac{3}{4}''$ x $1\frac{1}{8}''$ and it is parallel with *H* and perpendicular to *V*. The other two rectangular faces are at 45° to *H*.

The bases of the ring are placed perpendicular to *V* and at 45° to *H* with the edge of the hole resting on the upper corner edge of the prism.

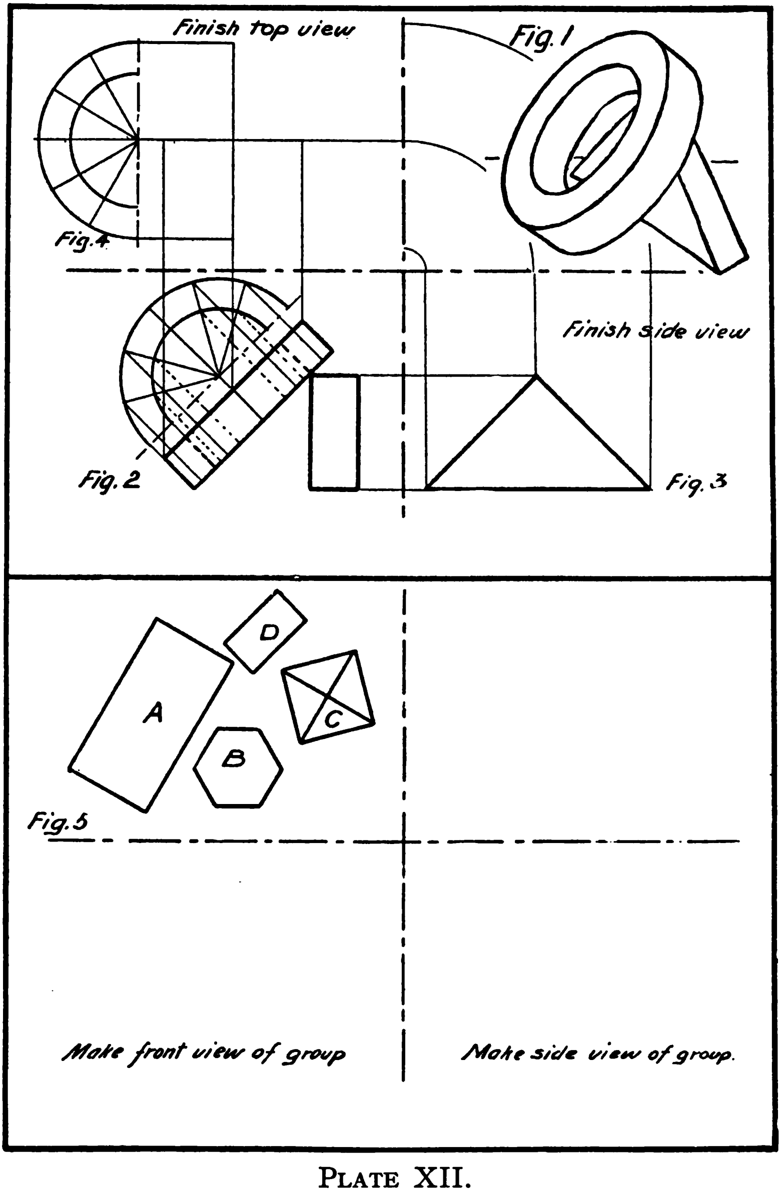

Finish top view
Fig. 1
Fig. 4
Finish side view
Fig. 2
Fig. 3
D
A
C
B
Fig. 5
Make front view of group
Make side view of group.

PLATE XII.

After drawing the front view of the two members of this group in the positions specified, it will be necessary to make a revolved view of the ring in order to show the circular face in its exact size so that it may be divided into elements which will assist in making the other two views of the ring. Another such view should be made to assist in obtaining the top view. The circles are indicated in Figures 2 and 4. It is necessary to represent only half the circle in each view for the reason that after dividing the half-circle into any even number of equal parts, projection lines from the points obtained would pass through the opposite points on the other half of the circle had it been represented. After drawing projection lines from all the points in the front view into the *H* plane, the horizontal projection lines from the points on the revolved view of the ring in the *H* plane, will intersect the vertical projection lines, giving points through which the outlines of the top view of the inclined ring may be drawn. The side view may then be obtained by projecting from the top and front views.

50. A group consists of four solids indicated by their top views in Figure 5, Plate XII. *A* is a cylinder, $1\frac{7}{8}''$ diameter, $3\frac{3}{4}''$ long, with ends at 30° to *V* and perpendicular to *H*. *B* is a hexagonal prism, $1\frac{5}{8}''$ between parallel faces and $1\frac{1}{4}''$ high. *D* is the end of a rectangular prism which is $1''$ x $1\frac{1}{2}''$ x $3\frac{1}{2}''$, with its lateral faces at 45° to *V* and its ends parallel with *H*. *C* is a pyramid with the front edge of the base at 15° to *V* and the base is parallel with *H*. Its base is $1\frac{3}{4}''$ x $1\frac{3}{4}''$ and its altitude is $3\frac{3}{4}''$. Represent three views of this group. Pupil may decide on the placing of each member of the group in regard to its position in relation to the other members of the group.

The Intersection of Surfaces

When a plane or curved surface meets another surface at an angle, the line separating the two surfaces is called the *line of intersection.* In plane-sided figures the outline of intersection is composed of straight lines. If either of two intersecting surfaces is a curved surface, their common line of intersection is a curved line except in a few special cases, occurring under certain conditions.

When one of the surfaces is that of a solid having a uniform cross section as in a cylinder or a prism, its end view will show whether the surfaces intersect in one continuous line or in two separate lines.

In general, the line of intersection between two surfaces is obtained by passing one or more auxiliary planes in such a manner as to cut some easily constructed sections, such as straight lines or circles, from each of the given surfaces; the meeting-points of the sections lying in any auxiliary plane will lie in the line sought.

The application of this principle just stated becomes much simplified whenever any face of either surface is so situated that its projection is in a line. This will be illustrated in the problems which are to follow. *The pupil will save much time and trouble if he will number or letter each point of the problem as soon as it is determined in the drawing.*

Drawing Problem 51. Make the top and front views of the square prism intersected by the rectangular prism epresented in Figure 81. The square prism is 1½″ x 1½″ x ¾″ and the rectangular prism is 1″ x 2″ x 3½″. Develop he surfaces of the prisms. This problem is drawn as repreented in Plate XIII. Draw both views of the square prism

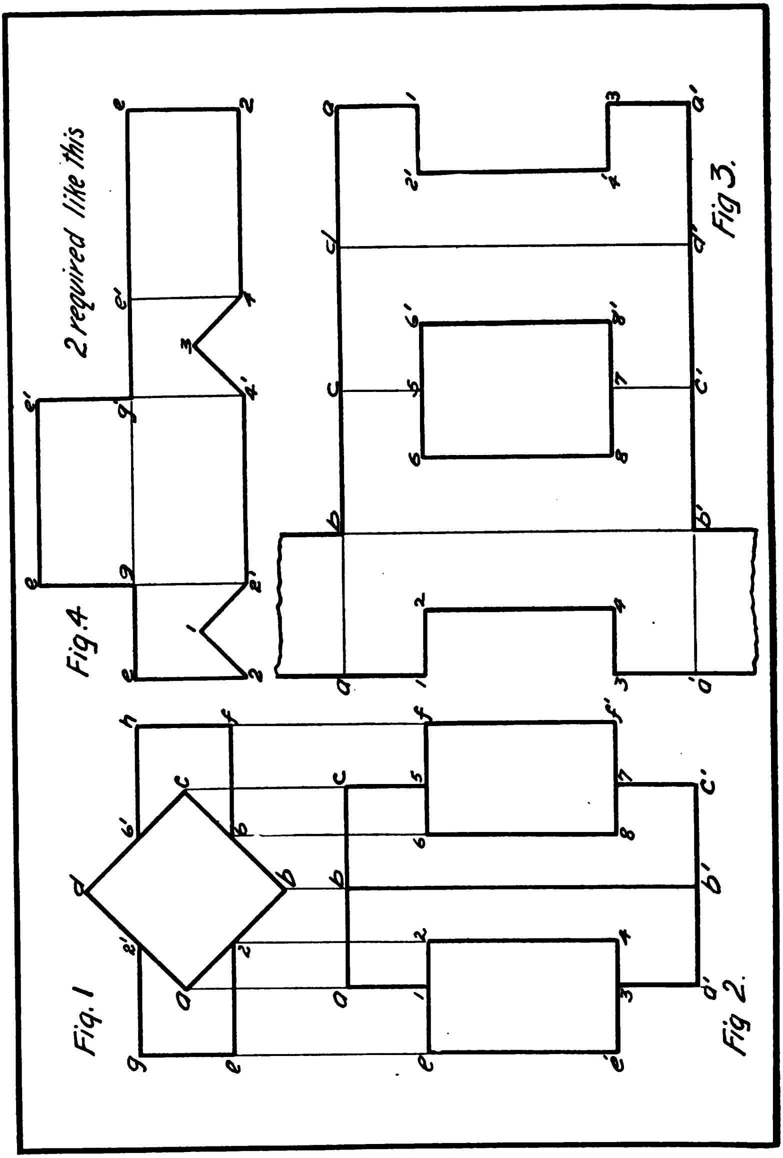


Fig. 1
Fig 2.
Fig 3.
Fig. 4
2 required like this
a
b
c
d
e
f
g
h
2'
6'
a'
b'
c'
d'
e'
f'
g'
1
2
3
4
5
6
7
8
4'
6'
8'
2'

PLATE XIII.

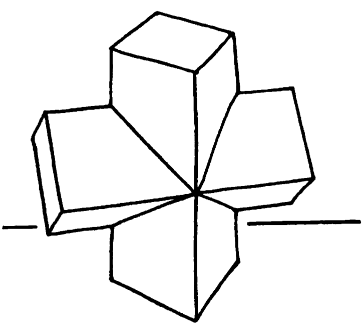


FIGURE 80.

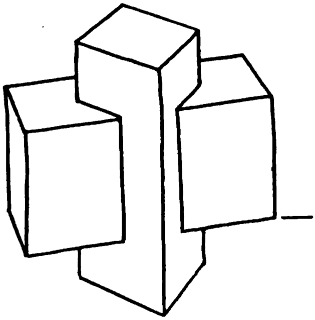


FIGURE 81.

and then represent the rectangular prism in the position indicated in the drawing. Designate the limiting points of each prism by letters and the points of intersection by numbers. In the top view, the line *e-f* of the rectangular prism intersects the surfaces of the square prism, the top views of which are indicated by the lines *a-b* and *b-c*, at *2* and *6*. These points, *2* and *6*, determine the length of the lines *e-2* and *6-f* in both views as will be seen when they are projected into the front view. Both views of the intersecting prisms indicate that each of the lateral surfaces of the square prism are penetrated by some part of the rectangular prism at equal distances from the corners *a-a′* and *c-c′* of the square prism. The front view of the square prism shows that parts of these corners from *1* to *3*, and *5* to *7*, are cut away by the intersecting rectangular prism. The lines of intersection in this view are *2-4* and *6-8*. In the development of the surfaces of the square pyramid, the positions of the points *1-3* on the lines *a-a′* and *5-7* on the line *c-c′*, may be determined by measurement or projection from the front view. The distances *1-2* and *5-6* must be measured in that view which represents the true length of these lines. The limiting lines of the square in the top view are parallel with *H* but at an angle to *V* therefore their true length according to principles "*c*" and "*d*" page 63, is to be measured in the top view. As *2* is a point projected on *a-b* its exact distance from the corner *a-a′* must be measured in that view which shows the exact width of the surface *a-a′*, *b-b′*.

This distance then is *a-2* of the top view and the measurement may be transferred to the development at each side of the lines representing the positions of the corners *a-a′* and *c-c′*.

Figure 4 of the plate represents the surface pattern for the parts of the rectangular prism projecting from the corners of the square prism. As both parts are exactly alike but one pattern is necessary and a statement should be made on the drawing of the number of pieces required.

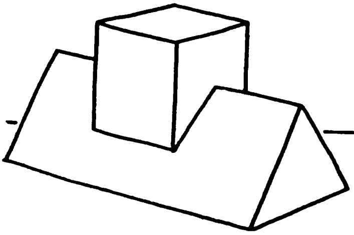


FIGURE 82.

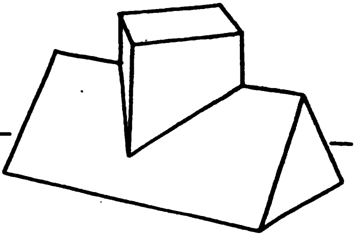


FIGURE 83.

Drawing Problems.

52. Make top and front views and develop surfaces of two intersecting square prisms as suggested in Figure 80. The prisms are each 1⅜″ x 1⅜″ x 3⅝″. The lateral faces of the vertical prism are at 45° to *V* and perpendicular to *H*. The lateral faces of the horizontal prism are at 45° to both *H* and *V*.

53. An equilateral triangular prism with lateral faces 2¼″ x 4″ is intersected by a prism which is 1¼″ x 1¼″ projecting 1″ above the top edge of the triangular prism as indicated in Figure 82. The bases of the triangular prism are parallel with *V* and perpendicular to *H*. Locate the square prism at the center of the top edge of the triangular prism,

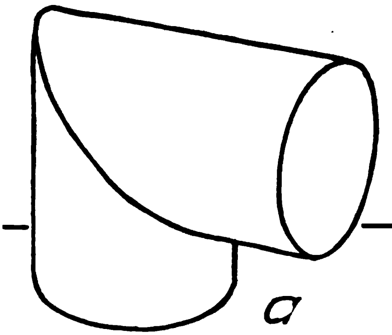


FIGURE 84.

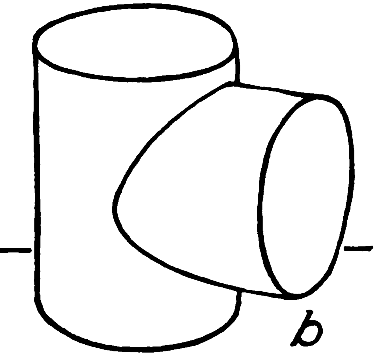


FIGURE 85.

with two of its faces parallel with the lateral edges of that prism. Draw three views and develop the surface patterns of each prism.

54. Represent the same intersecting prisms described in problem 53 but having the square prism turned so that one of the diagonals of the end is parallel with the lateral edges of the triangular prism as in Figure 83. Develop surface patterns.

55. Make two views and lay out surface patterns for a two-part right-angled elbow illustrated in Figure 84. The cylinders are each $2\frac{1}{8}''$ diameter and the length at the longest part is $3''$. What, if any, is the difference between the developments of the surfaces of the cylinders in this elbow and the development of the frustum of the cylinder represented in Plate XI, page 78? What would be the best way to lay out the patterns for this elbow in order that the material could be cut without any or but little waste?

56. Make front and top views and develop surfaces f two cylinders, one of which is $2\frac{1}{4}''$ diameter and $3\frac{1}{2}''$ high, ntersected at right angles by a smaller cylinder, $1\frac{3}{4}''$ diamter, projecting $1\frac{1}{2}''$ from the side of the larger cylinder, s suggested in Figure 85 and the drawing, Plate XIV.

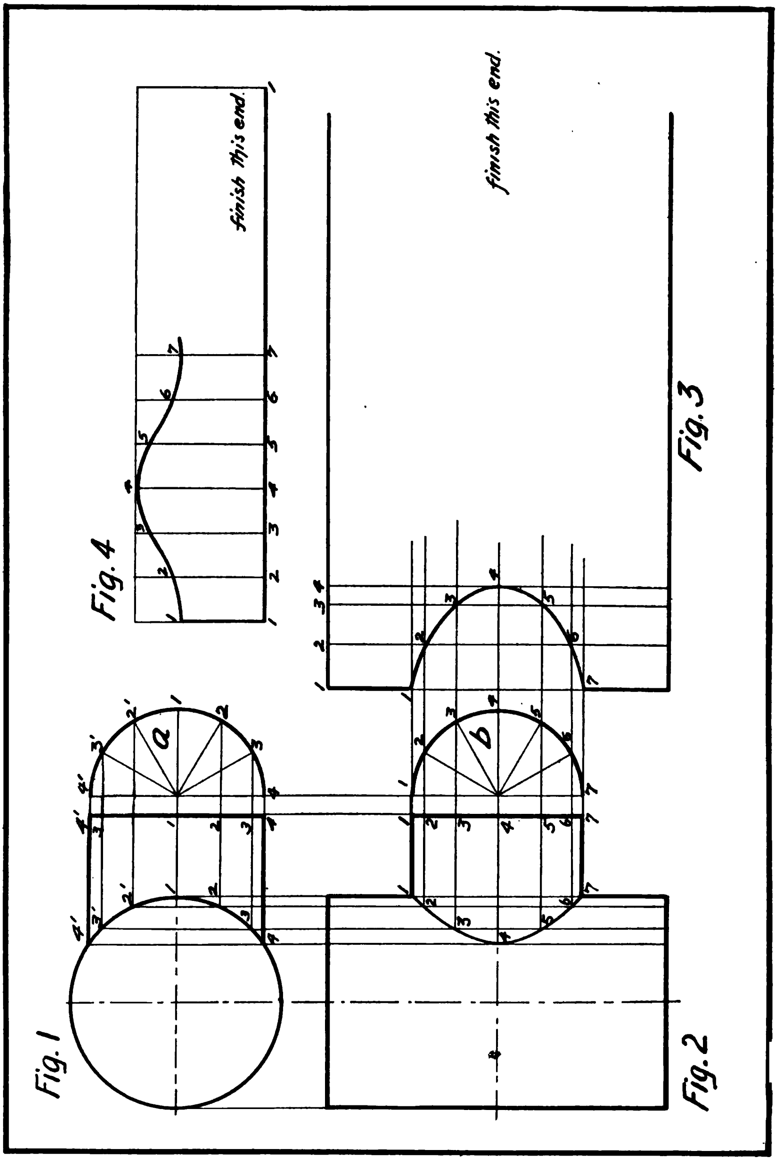


Fig. 1
Fig. 2
Fig. 3
Fig. 4
a
b
finish this end.
finish this end.
1
2
3
4
5
6
7
1'
2'
3'
4'

PLATE XIV.

In making this drawing it is necessary to make half end views as suggested at *a* and *b* in order to assume elements to use in obtaining the line of intersection and which will also aid in laying out the surface pattern. The points assumed in *a* are projected across the surface of the smaller cylinder to the surface of the larger cylinder, from which they are projected into the front view where they are intersected by projection lines from the points assumed in *b*. The line of intersection is traced through the points where the horizontal and vertical projection lines from corresponding points meet. The rectangle forming the surface pattern of the large cylinder should then be laid out and the positions of the vertical elements of the cylinder obtained from the top view, (Figure 1). The outline of the line of intersection may then be determined by projection or measurement from the front view, (Figure 2). The size of the rectangle (Figure 4) containing the surface layout of the smaller cylinder is determined by the length of its circumference and the length of the longest element in this cylinder. The lines representing the elements should then be drawn in their proper positions and the length of each measured in either the top or front views and transferred to its corresponding line in the rectangle. The curved outline caused by the intersection of this cylinder and the larger cylinder may then be traced through the points thus obtained.

Drawing Problems.

57. Make three views and develop the surfaces of two cylinders (Figure 86), one of which is $2\frac{1}{8}''$ diameter and $3\frac{1}{2}''$ high, intersected at an angle of 45° by a smaller cylinder, $1\frac{3}{4}''$ diameter. The distance from the top of the larger cylinder to the intersection of the center lines is $\frac{5}{8}''$. From this point to the base of the smaller cylinder is $3\frac{1}{8}''$. The front view of these cylinders is indicated at *2*, Figure 86. The proportions of this problem are such that the position of the surface patterns should be represented by rectangles having their longest sides parallel with the end margins of the drawing paper. This will cause all points in these developments to be obtained by measurement rather than by projection.

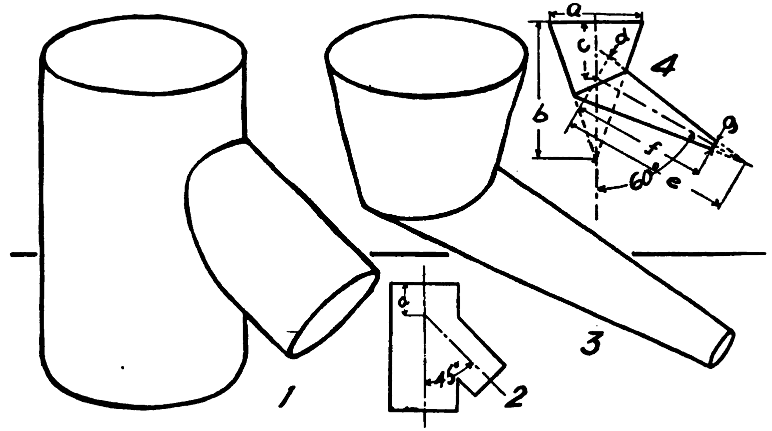


FIGURE 86.

58. Draw a front view only as represented in 4, of the funnel suggested in 3, of Figure 86, and then lay out the surface patterns for the funnel. The proportions are:

$a = 3''$, $b = 4\frac{3}{4}''$, $c = 2\frac{1}{2}''$, $d = 1\frac{3}{4}''$,
$e = 5''$, $f = 3\frac{3}{4}''$, $g = \frac{7}{16}''$
Angle between center-lines$= 60°$

59. A rectangular prism having an end $1\frac{1}{4}'' \times 2''$, intersects a cylinder which is $2\frac{1}{4}''$ diameter, $3\frac{3}{4}''$ high, as indicated in Figure 87, making an included angle of 60° between the prism and cylinder. The distances a and b are $\frac{3}{4}''$ and $1\frac{1}{2}''$. Make front and top views and develop surfaces of both cylinder and prism.

60. An equilateral triangular prism having a base with sides $1\frac{3}{4}''$ long, intersects a cylinder which is $2''$ diameter, $3\frac{1}{4}''$ high, as indicated in Figure 88, making an included angle between prism and cylinder of 60°. The distances a and b are $\frac{7}{8}''$ and $1\frac{1}{4}''$. Make number of views necessary to assist in laying out surface patterns.

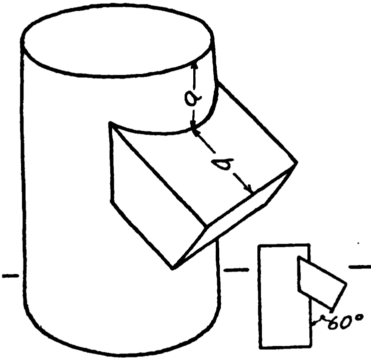


FIGURE 87.

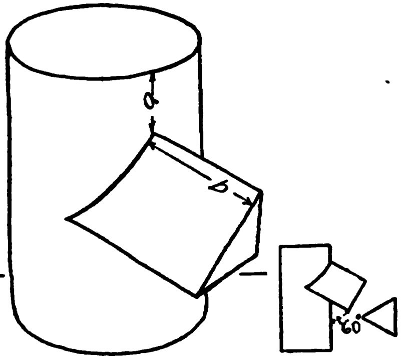


FIGURE 88.

61. Make necessary views and lay out surface patterns for the three-part elbow suggested in *a* and *b* of Figure 89.

62. Make all necessary views and layout surface patterns for the four-part elbow suggested in *c* of Figure 89.

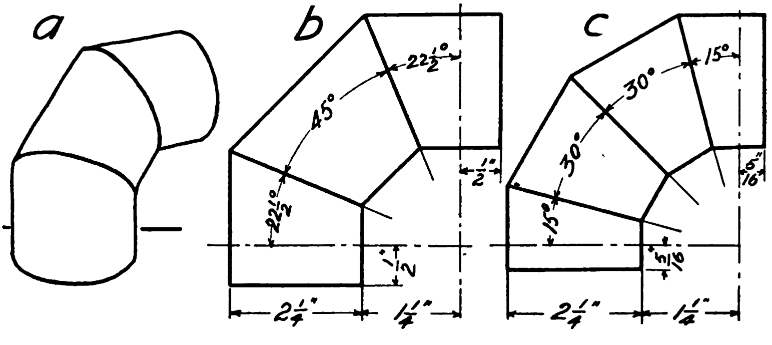


FIGURE 89.

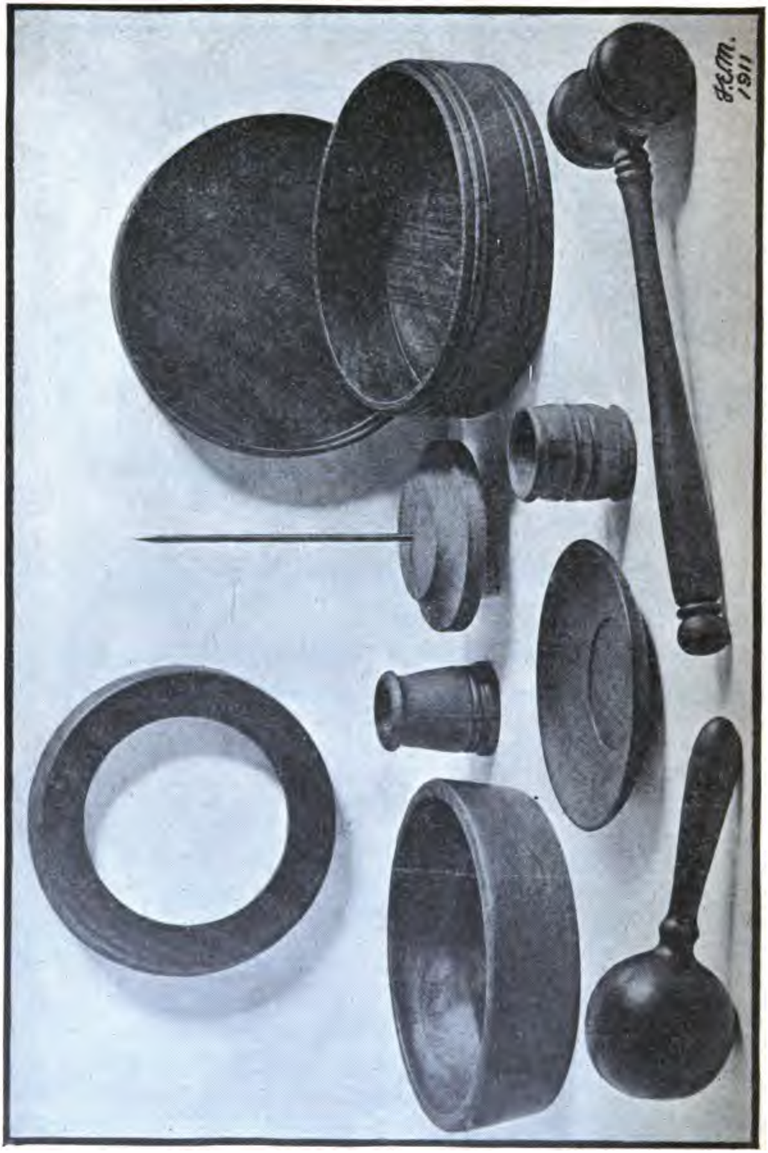


PLATE XV.

DRAWING PROBLEMS FOR THE WOODWORKING SHOPS

Constructive Design is the adaptation of the fundamental principles of design to the proportions, fitness of form, size and weight of materials used in the construction, of the special problem under consideration.

A constructive design for some particular object made by more or less original effort on the part of the pupil is a matter of great importance, and work of this character may have its beginning through the medium of a few simple problems especially selected for the purpose. In his first attempts to design, the average pupil is apt to aim far beyond his capacity, especially in regard to his constructive ability and the time at his disposal in which to work out and execute the problem that he has undertaken.

The secret of success in beginning constructive design lies in the selecting for the first problem an object that may call for a design which shall be of almost severe and extreme simplicity and then making the working drawing with the greatest care, attention to constructive detail and nicety of execution. Unless this is done, there is danger that many things that are impossible will creep into the design and thus make it of no practical value. Then there is the question of utility. If a problem is worth the time and attention of both shop and drawing room, the resulting product ought to be of value in itself. It should have some specific use and not be merely a thing to look at. With this thought in mind the following problems have been selected. The pupil should be guided by the suggested outlines and sizes presented and make a pencil drawing which is then to be traced and blueprints made for use in the shop. The accompanying halftone illustrations are made from photographs of work executed by pupils in their first year in the high school.

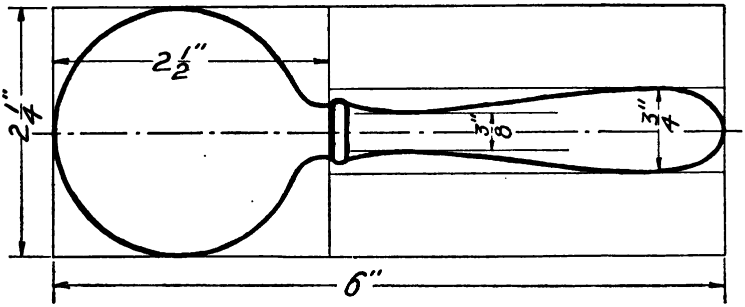


FIGURE 90.

Drawings for Wood-Turning: The problems presented in this section are so planned that the material for each problem may be cut to uniform size for class work in the shop. The heavy dot-and-dash lines in each of the working drawings indicate the stock in the rough. The dimensions given will allow for cutting off of centers, turning from the square to the round, and finish. Overall dimensions are stated in each problem for the largest possible design of good proportions. The outline design depends largely upon its simplicity of form and the best results in proportions are obtained through the spacing of diameters and lengths in their relation to each other. Drawings for these problems in wood-turning are to be made in the order in which the methods and processes of this subject are taught in the shop.

In making the design for each problem, the best method of procedure is to sketch several rectangles, each of which may include the whole outline. These rectangles should be of the largest possible size allowed by the material when turned from the square to the round. Sketch a center line through each rectangle as suggested in the sketch of the darning ball, Figure 90. Make several free hand sketches, for which suggestions are given in Plate XVI-A and select the design best suited for the purpose. The working drawing may then be made using the compass and curve ruler as illustrated in Figure 91. First draw one-half of the outline being very careful to locate all centers of arcs and to

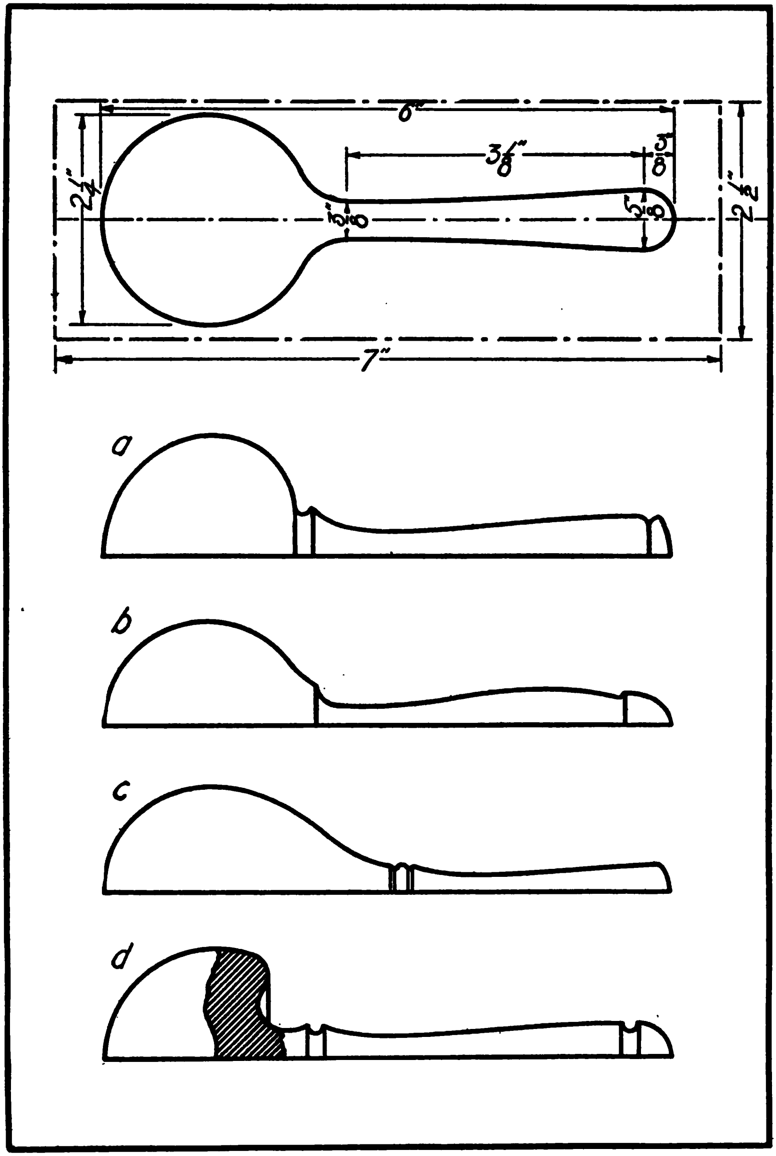


Plate XVI-A.

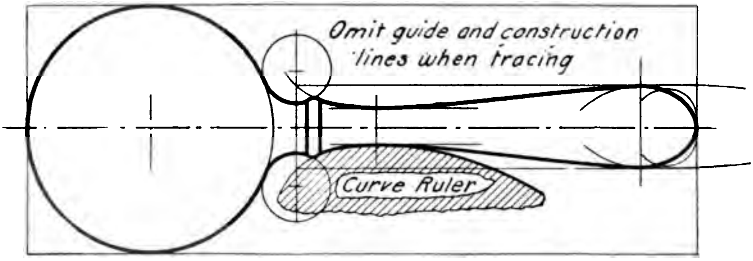
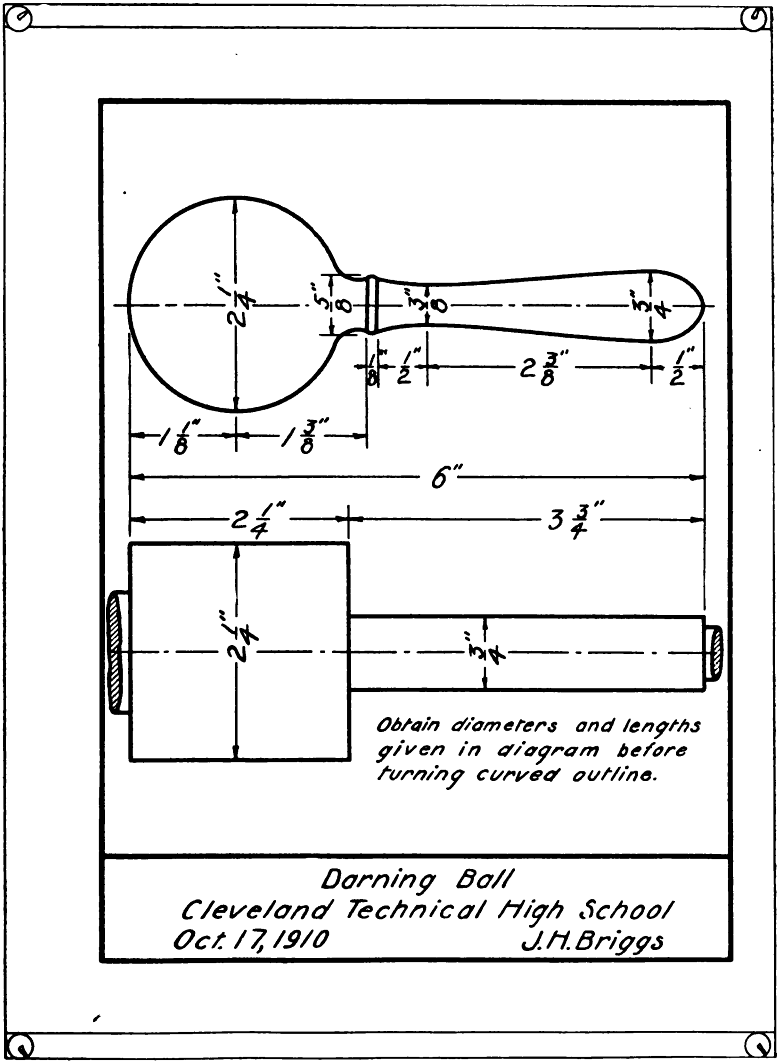


FIGURE 91.

mark the curves accurately. When this half has been satisfactorily completed the opposite half of the outline may then be reproduced by transferring all measurements to that part of the drawing, measuring carefully from the center line. Dimension the drawing, locating each dimension in its proper position and checking all subdivisions in order to be sure that their sum equals the overall dimension. The title for all wood-turning drawings should be similar to that shown in the finished drawing of the darning ball given in Plate XVI-B. The spacing of guide lines for the title may be found in Figure 22, Page 37.

63. The Darning Ball. PLATE XVI-A. The rough stock for this problem is $2\frac{1}{2}''\times2\frac{1}{2}''\times7''$, and is represented in the drawing by the heavy dot-and-dash lines. By allowing $\frac{1}{4}''$ for turning from the square to the round, and $\frac{1}{2}''$ at each end for cutting off, the largest possible design may be inclosed in a rectangle $2\frac{1}{4}''\times6''$. Sketch several rectangles of this size including center lines. For good proportions in the design the head should not be longer than $2\frac{1}{2}''$ and the handle ought not to be more than $\frac{3}{4}''$ or less than $\frac{3}{8}''$ in diameter.

64. The Gavel, PLATE XVII, consists of two parts, the head and the handle. Detail drawings of each part should be made. Length of tenon on handle to be $\frac{1}{8}''$ more than half of the diameter of the head at the center. The lines for the ends of the head must be arcs of a circle. Avoid a square shoulder at the intersection of the head and handle.



Obtain diameters and lengths given in diagram before turning curved outline.

Darning Ball
Cleveland Technical High School
Oct. 17, 1910 J.H. Briggs

PLATE XVI-B.

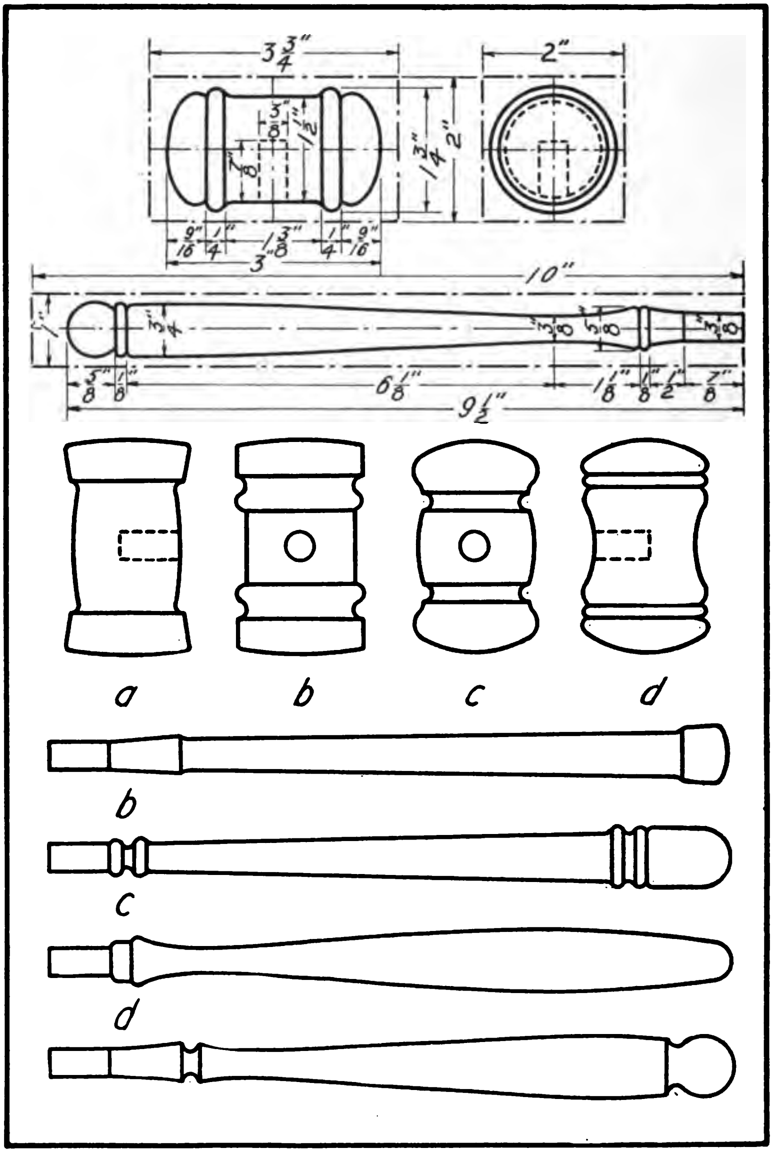

3 3/4"
2"
3/8"
1/2"
7/8"
1 3/4"
2"
9/16"
1/4"
1 3/8"
1/4"
9/16"
3"
10"
1"
3/4"
3/8"
5/8"
3/8"
3/8"
1/8"
6 1/8"
1 1/8"
1/8"
1/2"
7/8"
9 1/2"
a
b
c
d
b
c
d

PLATE XVII.

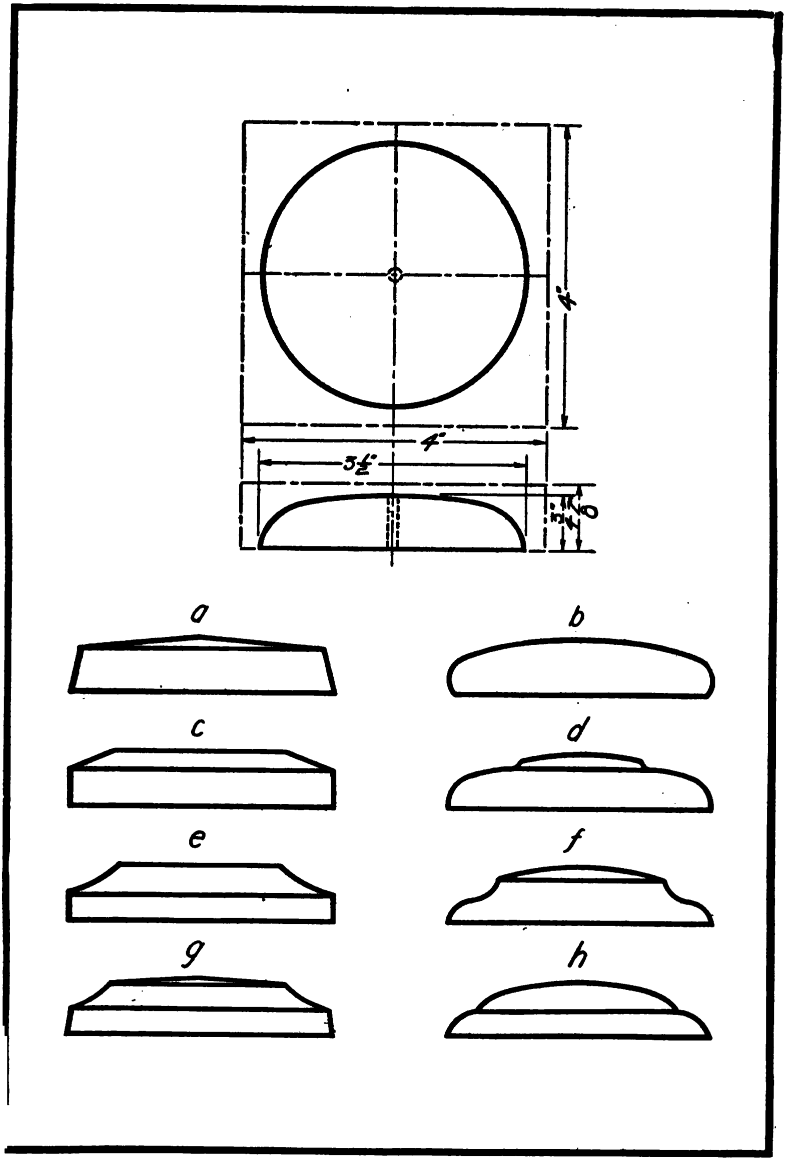


PLATE XVIII.

65. **The Paper File Base.** Plate XVIII. The paper file has a base and a wire spindle, which is made of $\frac{5}{32}''$ brass wire, 6″ long with one end sharpened to a point as shown in Plate XV. The wire driven through the center of the base and one end is flattened to prevent it from coming out. Simple, straight or curved line designs are to be preferred to intricate outlines having deep cuts and sharp corners. The base must be made as heavy as possible to prevent the file tipping over.

66. **The Picture Frame.** Plate XIX. Make top and front views. Indicate cross section of one-half the front view as shown in the drawing in order to make clearer that part of the design for the front and the recess for the glass and picture in the back of the frame.

67. **The Pin Tray.** Plate XX. This drawing should also show partial section in the front view. Several drawings for alternative designs may be worked out.

68. **The Napkin Ring,** Plate XXI, should not be less than $\frac{3}{16}''$ in thickness. This will necessarily limit the design to shallow cuts in order to avoid cutting through the piece. Round the inside corners slightly.

69. **The Match Holder.** Plate XXII. This problem differs from the napkin holder in that it offers opportunity of greater possibilities in the design. The base ought to be larger than the top.

70. **The Bowl.** Plate XXIII. Simplicity of outline should be the aim in this problem. Plain bands may be utilized in breaking up the surface which will demand careful planning of the spaces.

71. **The Box.** Plate XXIV. May be made in two sizes. In the large box the top view may be omitted. Place the cover drawing $\frac{3}{4}''$ above the drawing of the lower part of the box and dimension each completely. No part of the box should be more than $\frac{1}{4}''$ in thickness. The cover is held in position by a rabbeted joint.

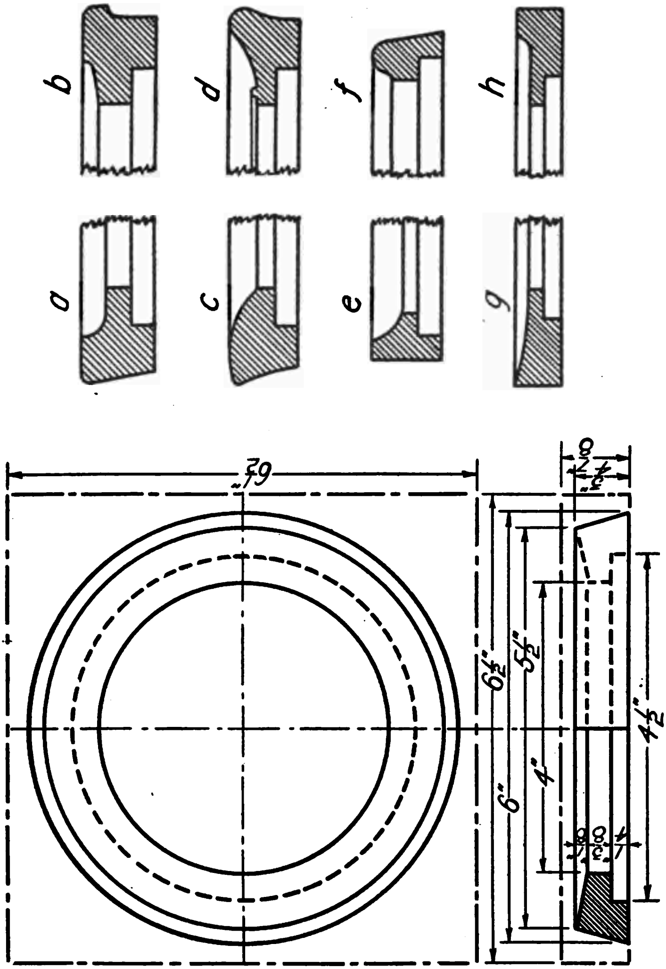


PLATE XIX.

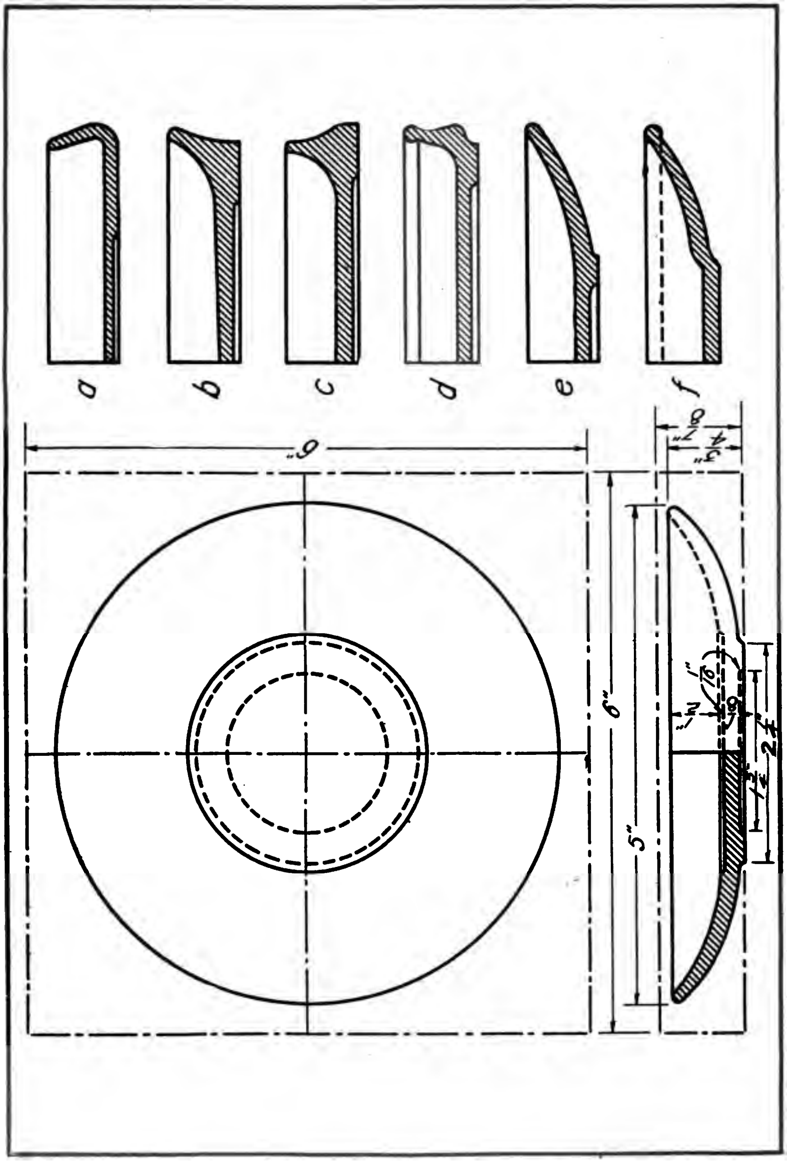


PLATE XX.

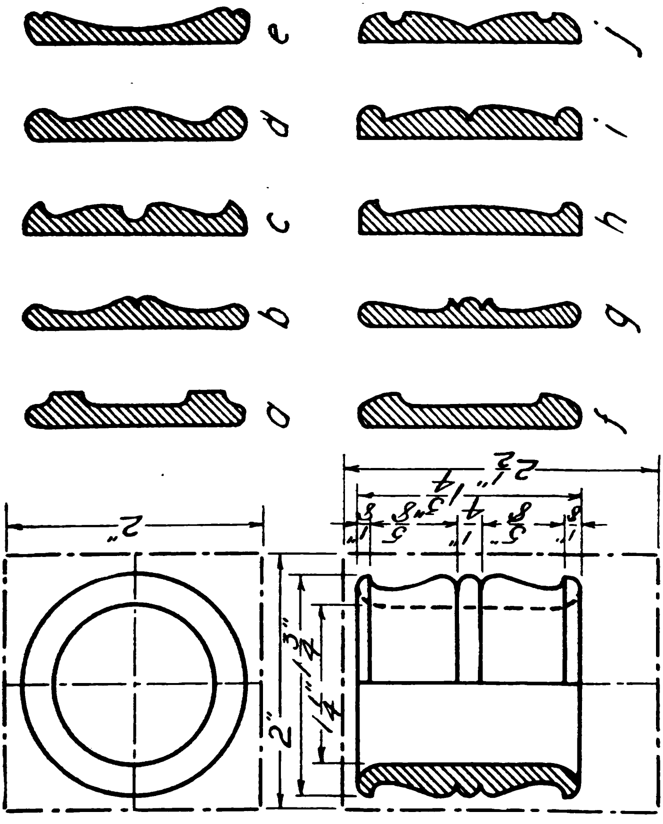


PLATE XXI.

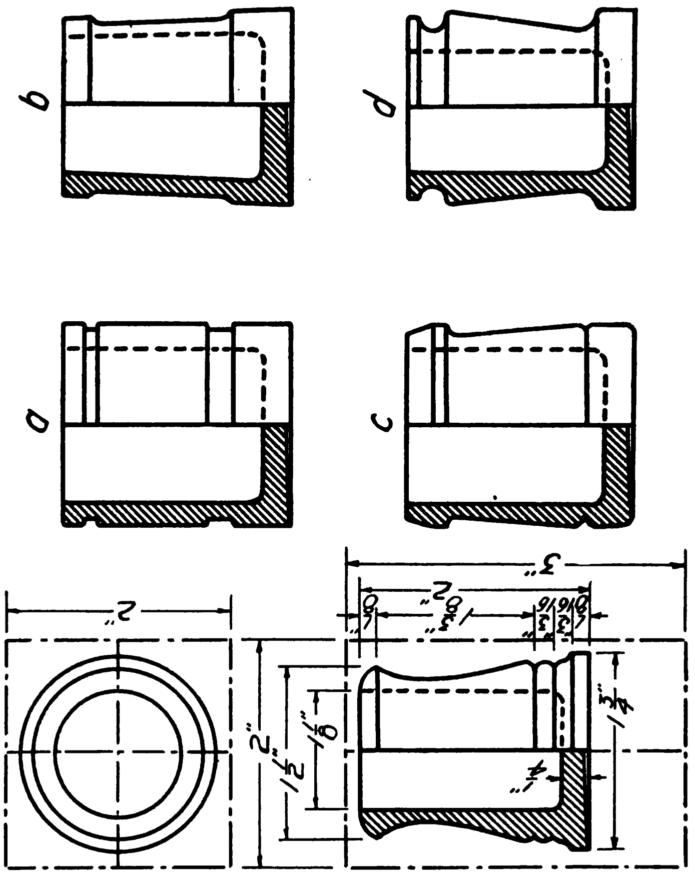


PLATE XXII.

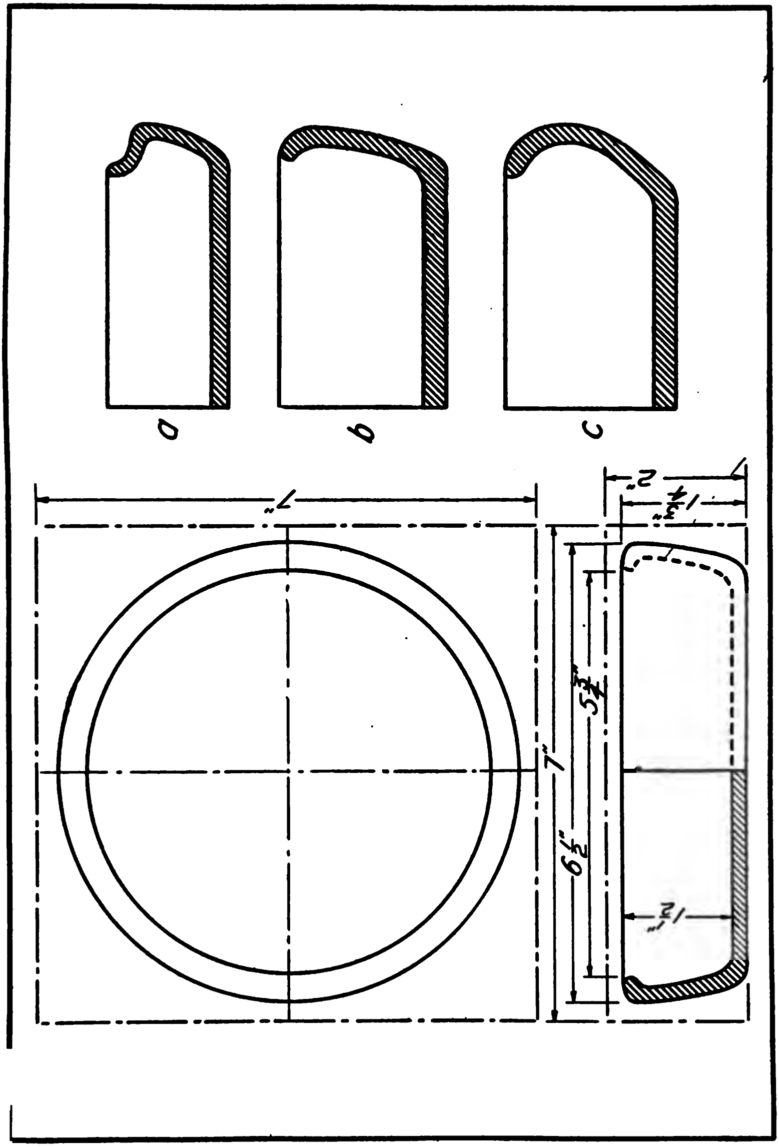


PLATE XXIII.

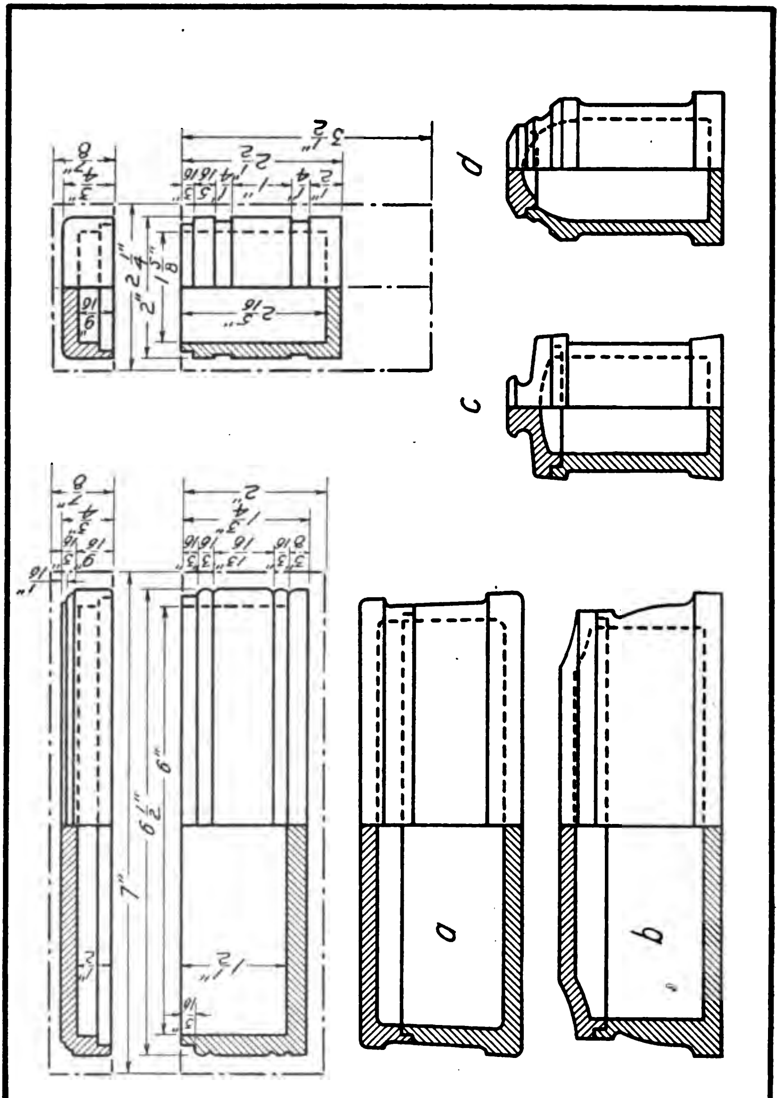


PLATE XXIV.

FURNITURE DRAWINGS

72. **The Book Rack**, PLATE XXV, is a problem in constructive design having considerable practical value as the first problem because of the few pieces required; its simplicity in construction and the opportunity for varied design in the outline of the end pieces. Figures 1 and 3 of the plate illustrate two methods of construction and it is necessary to decide first which method shall be adopted. After this decision has been made, draw carefully several rectangles which shall be the exact size of the end pieces. Locate the vertical center-lines and the lines which will indicate the location and size of the bottom piece. Sketch several outlines for the ends and select the most suitable design for the final drawing. Fold the paper on the vertical center-line and cut to the outline. This makes a pattern for the end which may be transferred to the final drawing and also used in the shop as a template in drawing the outline on the wood. The small sketches *a*, *b*, *c*, *d*, *e*, and *f* offer suggestions for either style of construction. The working drawing should be arranged and fully dimensioned as indicated in Figures 2 and 4. The *Mill Bill* for material in the rough should call for stock which is to be cut as follows:—

For Figure 1.	Bottom	$\frac{5}{8}''\times6\frac{1}{8}''\times17''$
	Ends	$\frac{5}{8}''\times6\frac{1}{8}''\times7\frac{1}{4}''$
For Figure 3.	Bottom	$\frac{5}{8}''\times6\frac{1}{8}''\times19\frac{1}{4}''$
	Ends	$\frac{5}{8}''\times6\frac{1}{8}''\times6\frac{1}{8}''$

A complete working drawing as it should appear when finished is shown in Plate XXVI. The mill bill and title should be placed as indicated in the upper right-hand corner of the drawing plate for which *B* size paper is required. The spacing for the arrangement of this title is given in Figure 23, page 38.

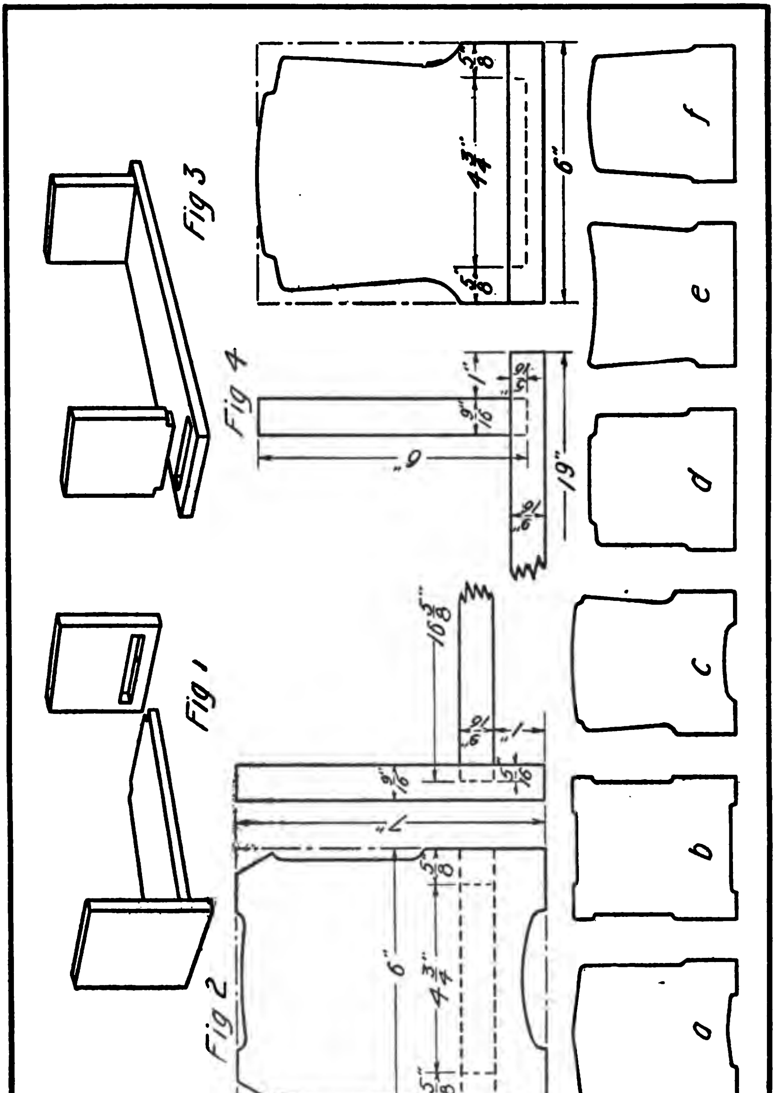


PLATE XXV.

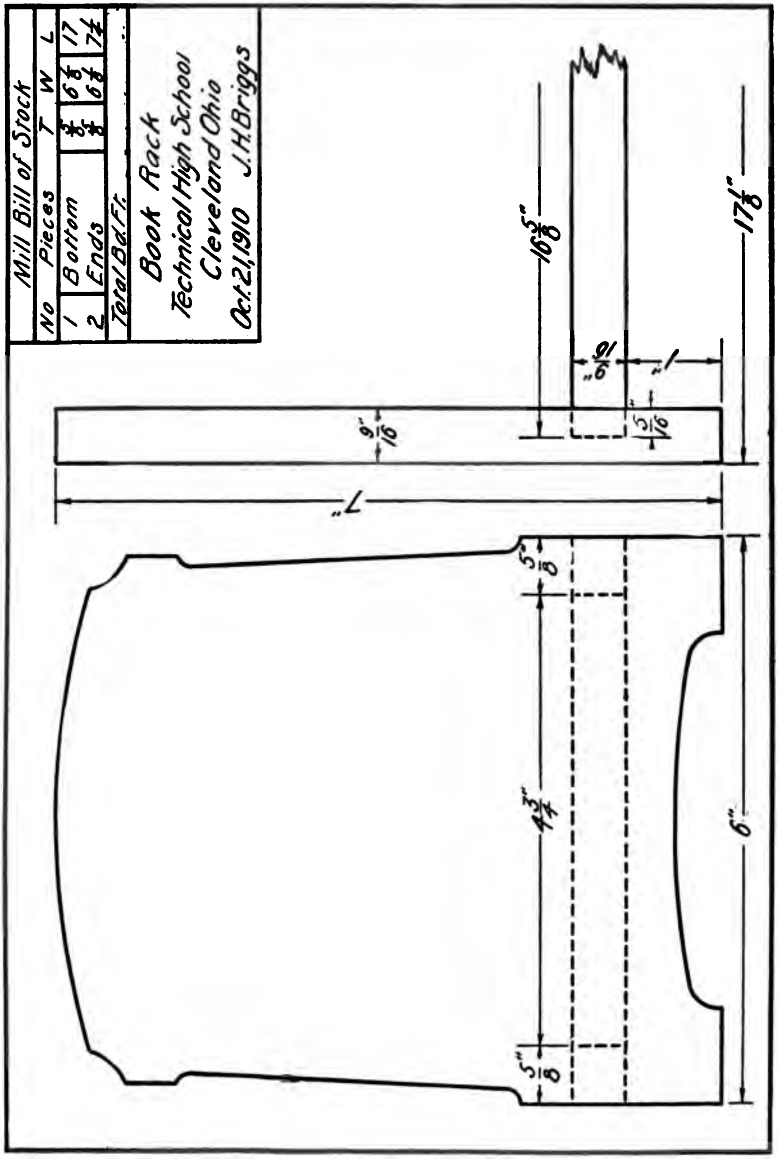

Mill Bill of Stock
No Pieces T W L
1 Bottom 5/8 6 1/8 17
2 Ends 5/8 6 1/8 7 1/4
Total Bd. Ft.
Book Rack
Technical High School
Cleveland Ohio
Oct. 21, 1910 J. H. Briggs
16 5/8"
17 1/8"
9/16"
1"
5/16
9/16
7"
5/8"
4 3/4"
5/8"
6"

Plate XXVI.

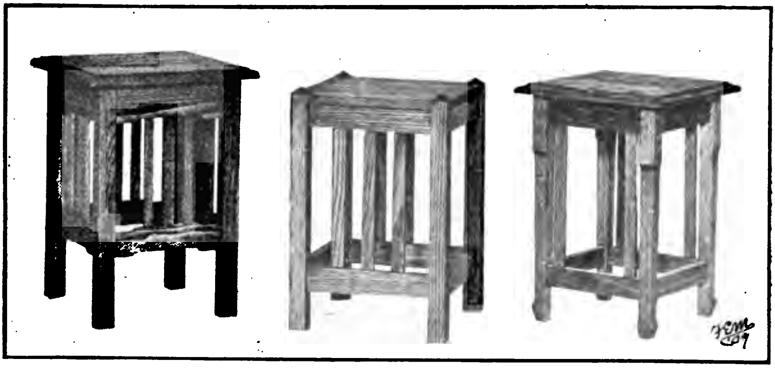


FIGURE 92.

73. **The Tabouret.** PLATE XXVIII. The general dimensions for this piece are as follows: top to be about 14″×14″; height, including top, about 19″. In laying out the arrangement of the drawing, sketch the positions; block out the front and top views, and space for title and mill bill allowing room for the various details. Because of the size of the tabouret, it will be necessary to make the drawing to a reduced scale (see page 10) in order to get the drawing on the *B* size paper. The largest possible scale that can be used in this case is a "*quarter size*" scale or a scale of ¼″ equal to 1″. Draw the top view, being careful about planning the location of the posts and the overhang of the top of the tabouret. In placing the rails, give particular attention to their size and their spacing in relation to the top and posts. If slats are used in the design, the spacing is more of a problem, and the position of the rails must be determined first in order that the slats shall have the proper length in proportion to their width and the distances between each other and the posts. Various combinations of the parts may be made in designing the tabouret, some of which are shown in Plate XXVII and others in Figures 92 and 97. Modifications of the outlines of the tops and in the shapes of the posts may also follow some of the suggestions given. The dif-

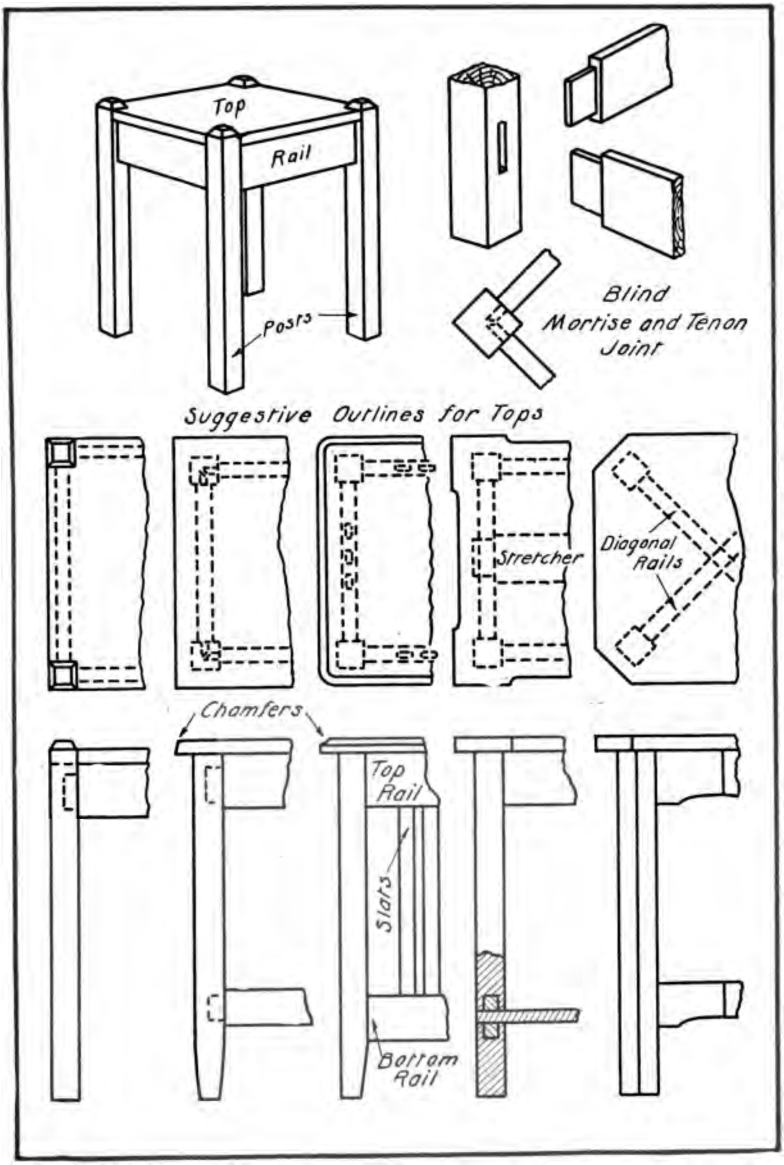

Top
Rail
Posts
Blind
Mortise and Tenon
Joint
Suggestive Outlines for Tops
Stretcher
Diagonal
Rails
Chamfers
Top
Rail
Slats
Bottom
Rail

PLATE XXVII.

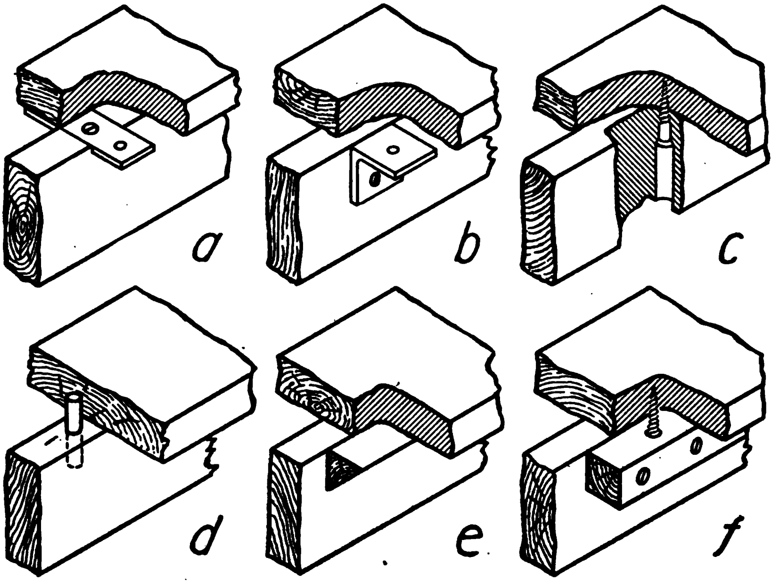
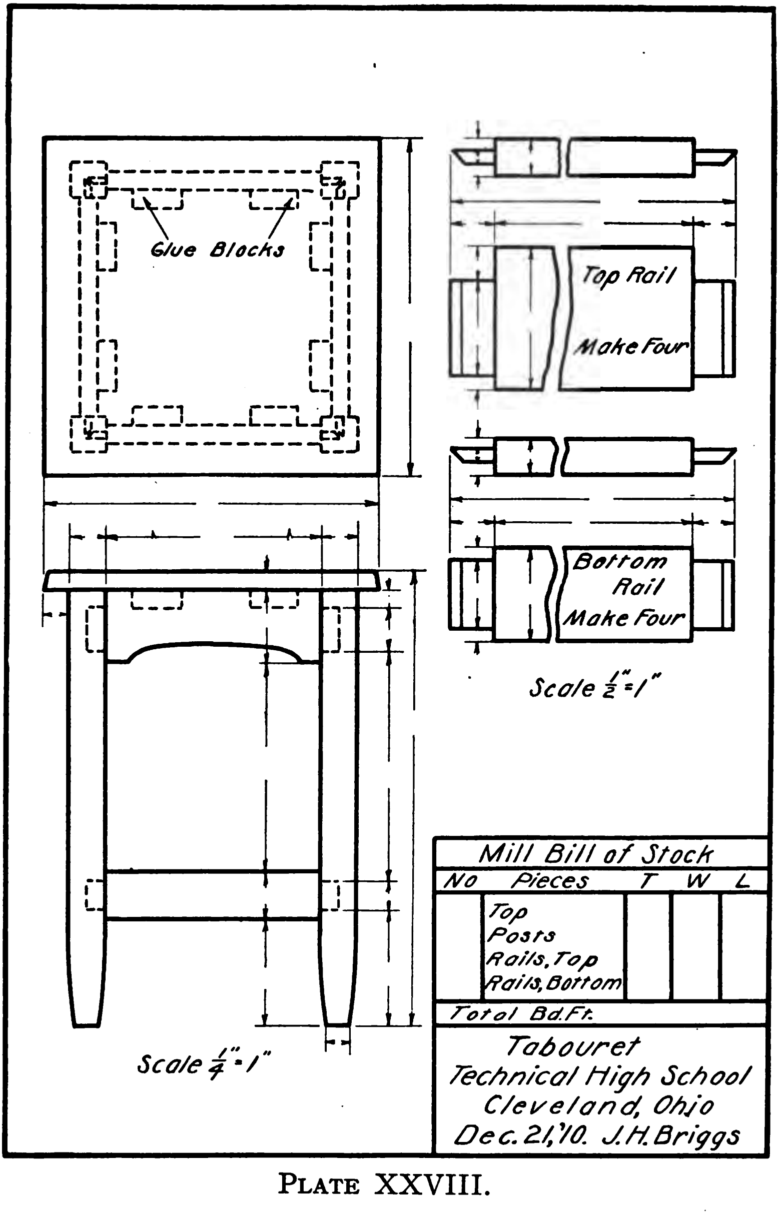


FIGURE 93.

ferent members are held together by glued blind mortise-and-tenon joints, with the exception of the top which may be fastened to the rails by any one of the methods shown in Figure 93. The working drawing is completed by dimensioning each part but the size of the drawing is such that if all dimensions are placed in the two views, they will necessarily be crowded together and detract from the appearance of the drawing. Detail drawings should be made of the rails and slats to a larger scale of "*half size*," or ½" equal to 1", thus making the drawing much clearer and more comprehensive. The *Mill Bill* should call for rough stock cut as follows:

Top	$\frac{7}{8}$"×14½"×14½"	Rails	$\frac{7}{8}$"×..."×..."
Posts	1½"× 1½"×19"	Slats	$\frac{5}{8}$"×..."×..."

74. **The Umbrella Stand.** PLATE XXIX, FIGURES 94 and 95. The overall dimensions of the umbrella stand should be about 12"×12"×30". The top and front views representing the assembled 'parts of the stand should be made to the



Mill Bill of Stock

No	Pieces	T	W	L
	Top			
	Posts			
	Rails, Top			
	Rails, Bottom			
Total Bd. Ft.				

Tabouret
Technical High School
Cleveland, Ohio
Dec. 21, '10. J. H. Briggs

PLATE XXVIII.

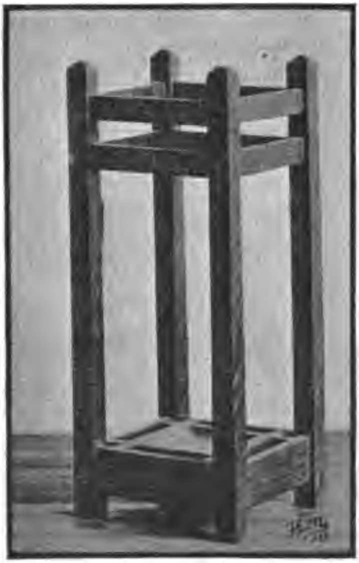


FIGURE 94.

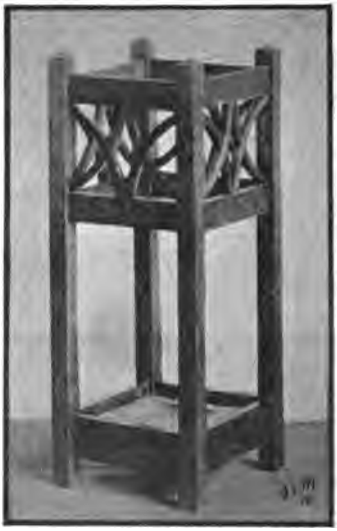


FIGURE 95.

quarter-size scale. The detail drawings of rails and pan supports should be made to a half size scale. The pan supports should be made of $\frac{3}{4}''$ square stock having cross lap joints, and are held in place by brads driven through the rails into the ends of each piece in the support. The pan should be made of 14 gauge sheet copper and formed to shape by hammering it into a hardwood block hollowed out for the purpose. The *Mill Bill* for rough stock should call for material cut as follows:—

Posts $1\frac{1}{2}''\times1\frac{1}{2}''\times30''$ Rails $\frac{7}{8}''\times\ldots''\times\ldots''$
Slats $\frac{5}{8}''\times\ldots''\times\ldots''$

75. **The Library Table,** PLATES XXX AND XXXI, should be from 28″ to 30″ high, having a top varying from 28″ to 36″ in width, by from 34″ to 54″ long, and from 1″ to 1½″ thick, depending largely on the space which it is to occupy. The posts should not be less than 2¼″ square for the smallest

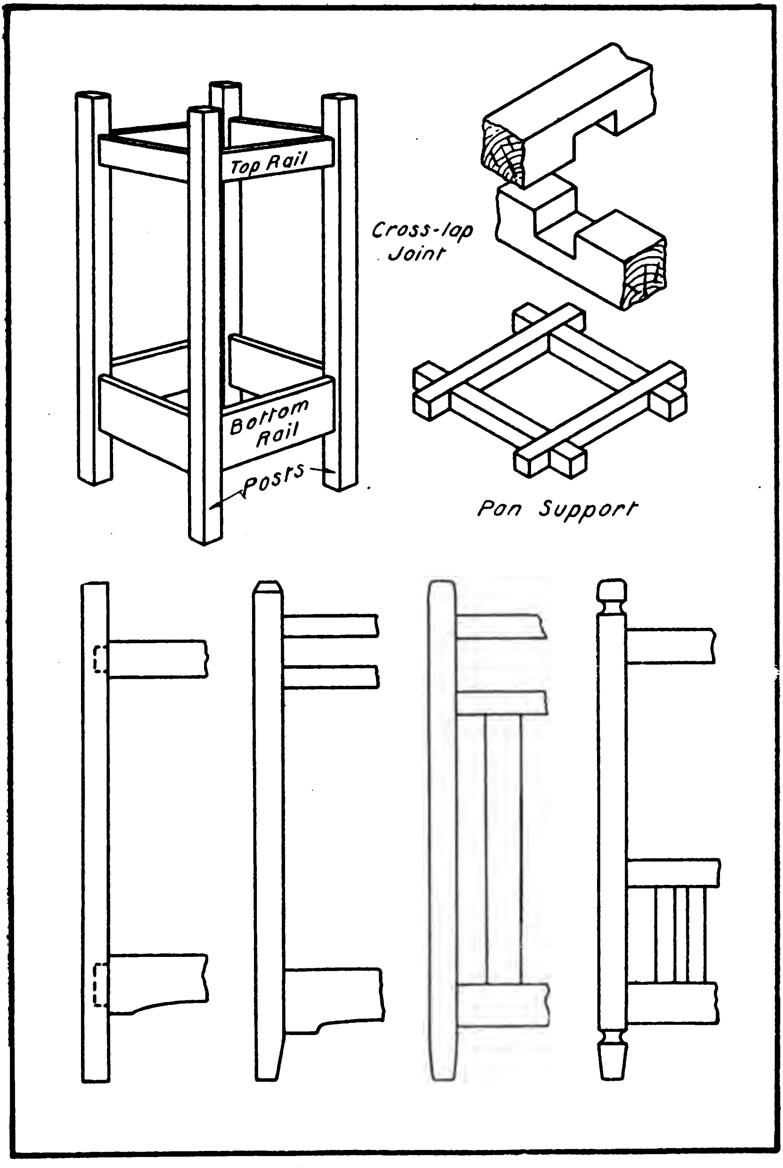


PLATE XXIX.

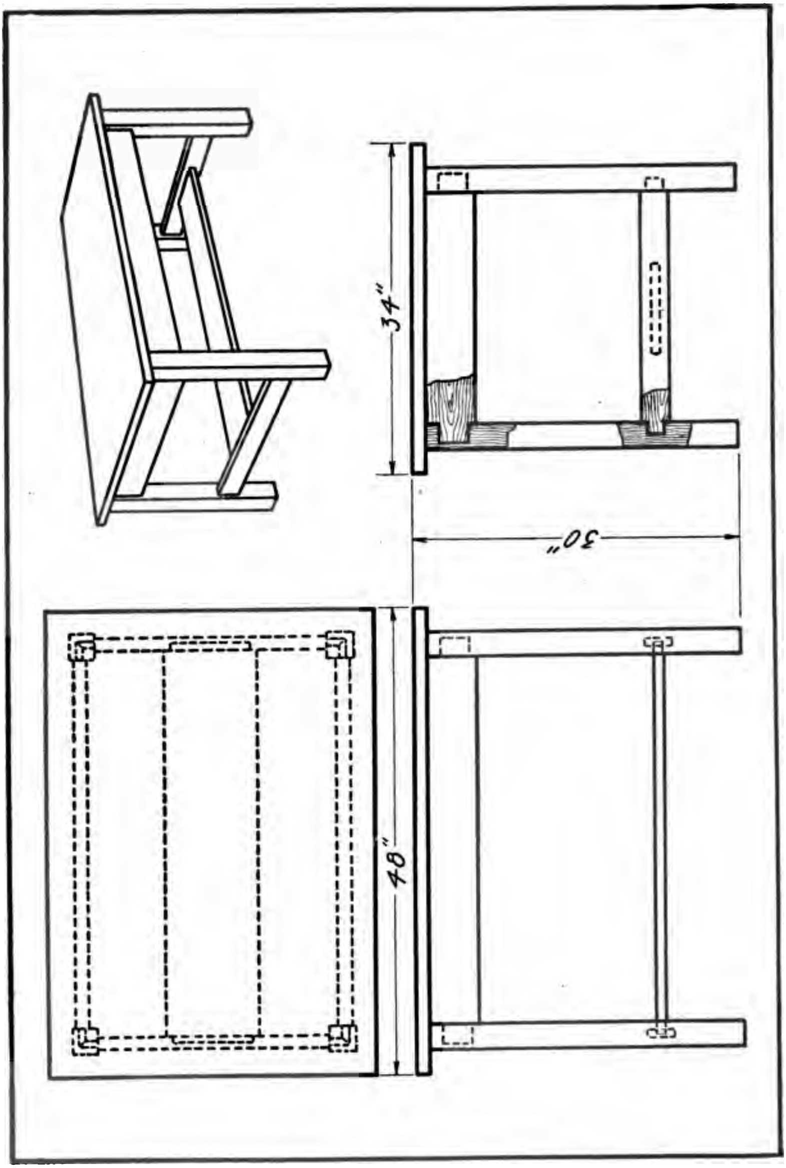


PLATE XXX.

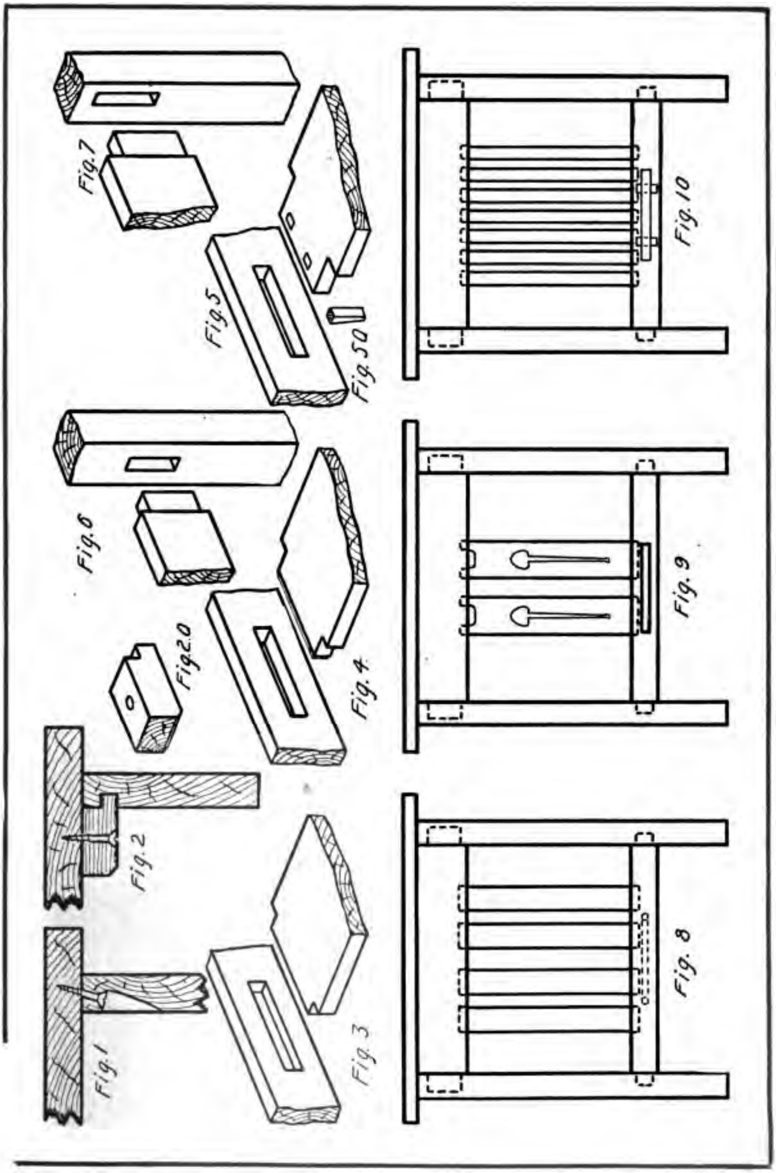


Fig.1
Fig.2
Fig.3
Fig.2.0
Fig.4
Fig.6
Fig.5
Fig.5.0
Fig.7
Fig. 8
Fig. 9
Fig. 10

PLATE XXXI.

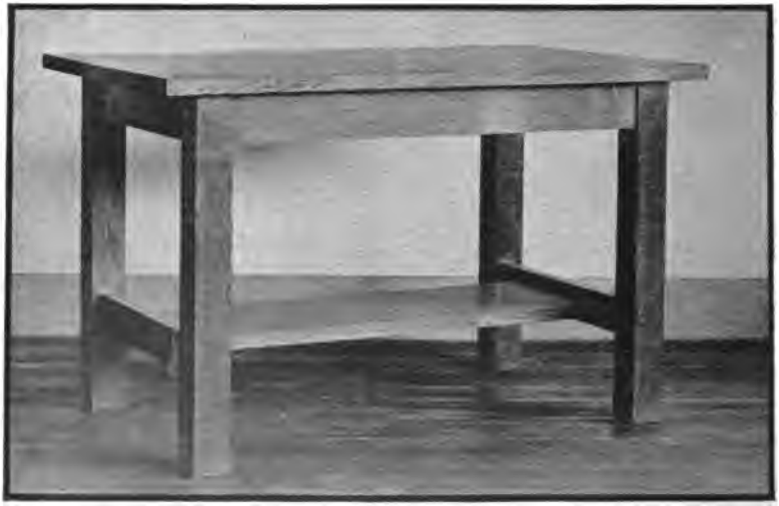


FIGURE 96.

size nor greater than $3\frac{1}{2}''$ square for the largest size table. The plates offer several good suggestions for arrangement of parts and as the general dimensions will vary according to the requirements, the planning of the proportions and the style of construction must depend upon the varying conditions.

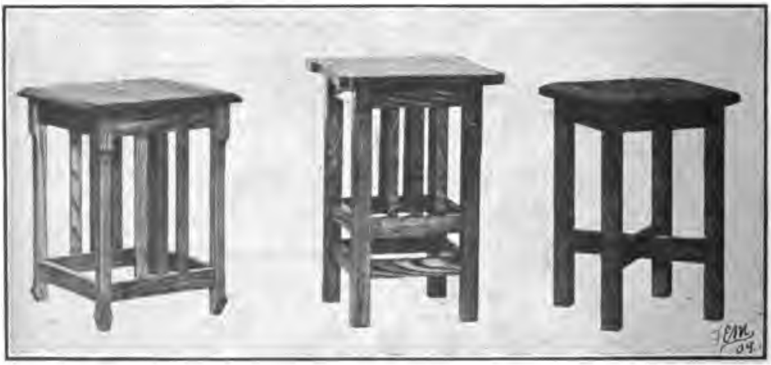


FIGURE 97.

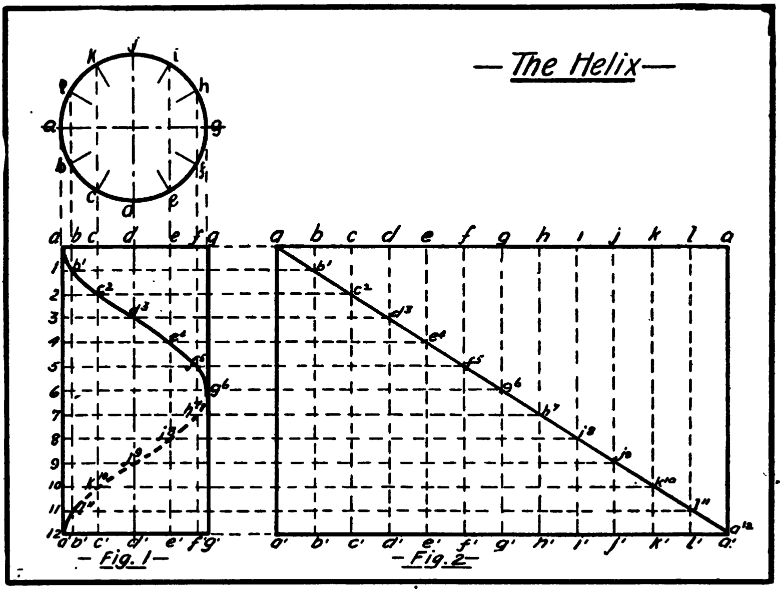
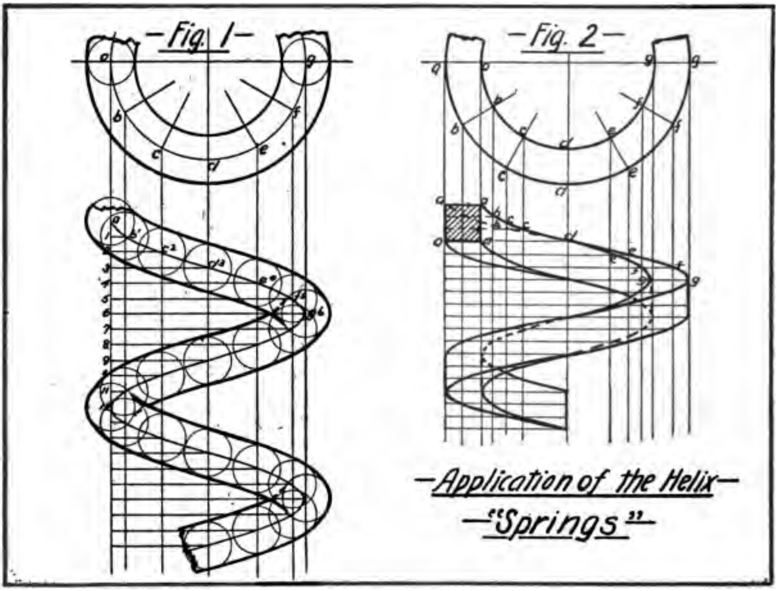


PLATE XXXII-A.

THE REPRESENTATION OF SCREW THREADS

In nearly all drawings of machine details it is necessary to represent screw threads. While these representations are usually conventional, it is essential that the pupil should know the source of the conventions. For this reason it is necessary to consider the *Helix* and its application in the representation of springs and screws.

The Helix. PLATE XXXII-A. The "*helix*"is the path of a point traced on the surface of a revolving cylinder as the point moves at a uniform rate of speed along a line which is parallel with the axis of the cylinder, and having some regular prescribed proportion of travel in this direction to each revolution of the cylinder. The distance between any two points in the path, measured parallel with the axis of the cylinder, is called the pitch of the helix.



—Application of the Helix—
—"Springs"—

PLATE XXXII-B.

Take a cylinder (Figure 1) and a rectangular piece of paper (Figure 2) with the side *a-a* equal to the circumference and the side *a-a′* equal to the height of the cylinder. Draw the diagonal and then wrap the paper about the cylinder. The curve which the diagonal takes is called the *helix*, and *a-a′* is called the *pitch* of the helix.

To draw a helix of one turn, having a diameter of 2½″ and a pitch of 4½″, first represent a cylinder of these dimensions. Divide the end view of the cylinder into any number of equal parts and the pitch of the helix (represented by the height of the cylinder) into the same number of equal parts. Letter or number the points of division in both views to correspond. At the intersections of projection lines from the points in one view drawn perpendicular to projection lines from the corresponding points in the other view, are the various points in the path of the helix which may be lined in with the curve ruler. The helix is the curve of the screw thread and is used in making the actual representation of the thread.

Application of the Helix.—Springs. PLATE XXXII-B. In making the drawing of the Coil Spring, when the spring is to be of round material, it is necessary to lay out the helix for the center line of the spring. (Figure 1.) Then by drawing circles equal in diameter to the size of the round material, the outside helices may be drawn tangent to these circles. When square material is used then it will be necessary to draw the four helices by projection as represented in Figure 2.

Drawing Problems.

76. Draw a helix of one revolution about a cylinder 2½″ diameter and 4½″ high. Make drawing using the development of the cylinder.

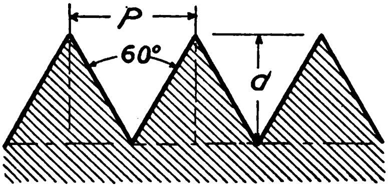
77. Draw a helix of 1½″ pitch, making three revolutions about a cylinder 4″ in diameter. Make drawing without using development of the cylinder.

78. Make a drawing of a coil spring which is to be made of ¾″ round material, the spring to be 4″ outside diameter and the pitch 2¼″. Length of spring, 6¾″.

79. Make a drawing of a coil spring which is to be made of material ½″ square in section, the spring to be 1½″ pitch, 4″ outside diameter, and 4½″ length of spring.

Questions.

1. What is the length of the helix in problem 76?
2. What is the height of the cylinder in problem 77?
3. What is the length of the material used in the spring called for in problem 78?
4. What is the inside diameter of the spring in problem 79?

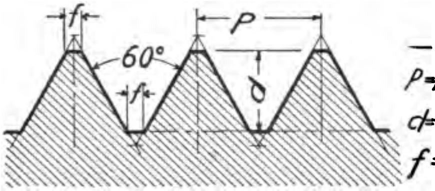


— Formula —

$p = \text{pitch} = \dfrac{1}{\text{No. thds per inch}}$

$d = \text{depth} = p \times .86603$

— Sharp V Thread —



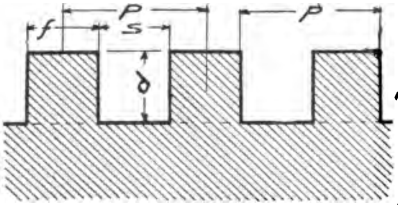
— Formula —

$p = \text{pitch} = \dfrac{1}{\text{No. thds per inch}}$

$d = \text{depth} = p \times .64952$

$f = \text{flat} = \dfrac{p}{8}$

— United States Standard Thread —



— Formula —

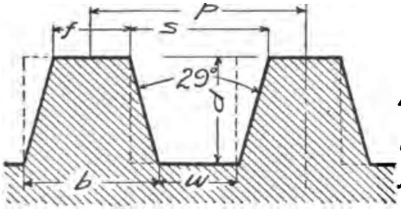
$p = \text{pitch} = \dfrac{1}{\text{No. thds per inch}}$

$d = \text{depth} = p \times .485$

$f = .5 \times \text{pitch}$

$s = f$

— Square Thread —



— Formula —

$p = \text{pitch} = \dfrac{1}{\text{No. thds per inch}}$

$d = .5p + .01$ | $S = .6293p$

$f = .3707p$

$w = .3707p - .0052$

— Acme 29° Thread — $b = .6293 + .0052$

PLATE XXXIII.

"A 'Screw' is a cylindrical bar upon which has been formed a helical projection or thread. The screw fits accurately into a hollow corresponding form called its 'nut.' Pairs of elements thus formed are used in machinery as (a) fastenings, in which case they are called bolts; (b) for adjusting the relative positions of two pieces; (c) for transmitting energy.

"Bolts or fastening screws are chiefly used to resist straining forces which act parallel to the axis of the bolt. A bolt differs from a rivet in that it permits the connected pieces to be easily disconnected when necessary."

(*Unwin-Machine Design*)

The *pitch of a screw* is the distance from the center of one thread to the center of the next thread, measured parallel to the axis of the screw. The *lead of a screw* is the distance its nut would travel along the axis of the screw in one turn of the screw. The lead of a single thread screw would equal the pitch, while the lead of a double or triple thread would be two or three times the pitch as the name would indicate. The *nominal diameter* of the screw is that of the cylinder into the surface of which the thread is cut. The *effective diameter* is the diameter of the screw at the bottom of the thread. The effective diameter is usually called the *root* diameter of the thread.

Threads in Common Use. PLATE XXXIII.

The *V* shaped thread is common for all screws used for fastening purposes, because of the shearing strength of the threads and the frictional holding power which is due to the pressure being inclined to the axis of the screw.

The Sharp V Thread is the thread most commonly used for rough work. Its outline is the basis of the *United States Standard* thread. The sides of this thread are equal in length to the pitch and are at an included angle of 60° to each other and to the axis of the screw.

The United States Standard Thread has the sides of the thread at an included angle of 60° to each other as in the sharp V thread, but they are one-eighth of the total depth of the V, short of meeting at both the top and bottom of the thread, thus making the actual depth of the thread equal to three-fourths of the depth of the sharp V. The number of threads per inch of the U. S. S. thread in relation to the diameter of the screw is determined by the formula:

$$\textit{No. thds. per inch} = \frac{1}{0.24\sqrt{(\textit{nom. dia.} + .625)} - 0.175}$$

and using the nearest even number to the result obtained.

The Square Thread is best adapted for transmitting motion when the load has to move in opposite directions. It is really rectangular in form, the depth being equal to .485 of the pitch, and the width of thread and space each equal to one-half the pitch. It is usually represented as square in the drawing. On screws of the same diameter, the pitch of the square thread is usually made twice that of the V thread. That is, an 8 pitch square thread would be used on the same diameter screw as a 16 pitch V thread.

The Acme Standard Thread is a modified form of the square thread used for screw gearing and lead screws in lathes and similar machines. The thread has an included angle of 29°, and in ordinary pitches will permit a clasp nut to be used on the screw which is not practical with the square thread. In drawing this thread it is permissible to draw the sides with the triangles giving an included angle of 30°. The pitch of the Acme thread is usually the same as for a square thread screw of the same diameter.

The method of drawing the actual helical curves of the V thread is illustrated in Plate XXXIV, but it is not necessary nor is it the custom for the draftsman to take the time required to make this lengthy geometrical construction in representing each thread in the drawing. He usually adopts some conventional method of representation which is suit-

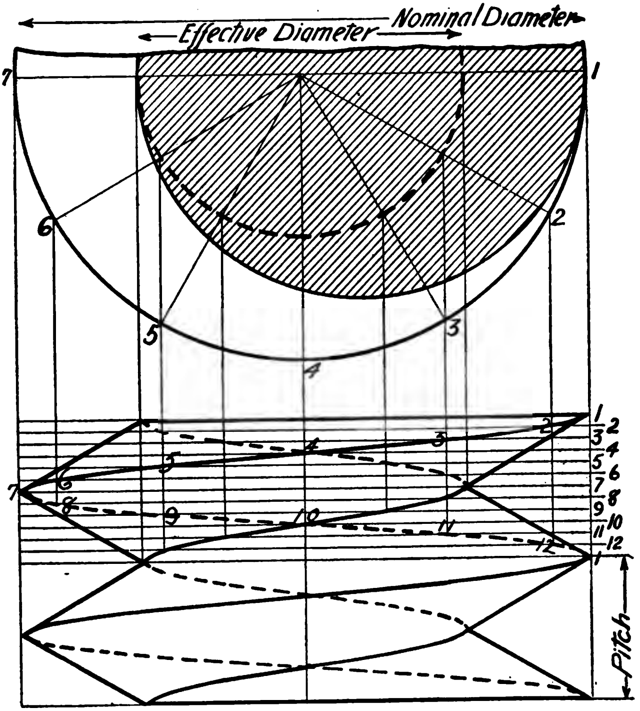


Fig. 1

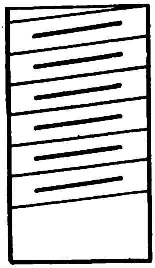


Fig. 2

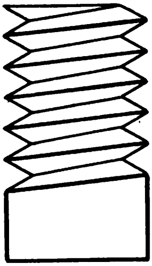


Fig. 3

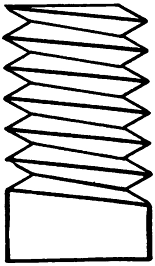


Fig. 4

Plate XXXIV.

able to the character of the drawing upon which he is working.

Figure 2 shows a very common convention for the sharp V thread. Figures 3 and 4 illustrate a more elaborate convention, both right and left-hand threads being indicated. When representing screw threads by conventional forms, a note stating the size of screw and pitch of thread should appear on the drawing.

Drawing Problems.

80. Make outline drawings of each of the threads shown in Plate XXXIII. The Sharp V and U. S. S. Threads to be one thread per inch or 1″ pitch. The Square thread to be two-thirds of a thread per inch or 1½″ pitch. The Acme thread to be one-half thread per inch or 2″ pitch.

81. Make drawings representing the actual helical curves of a Sharp V thread of 1½″ pitch, cylinder 6″ diameter.

82. Make drawings representing the actual helical curves of a Square thread of 1″ pitch, cylinder 6½″ diameter.

83. Make similar drawings of either the U. S. S. thread or the Acme thread.

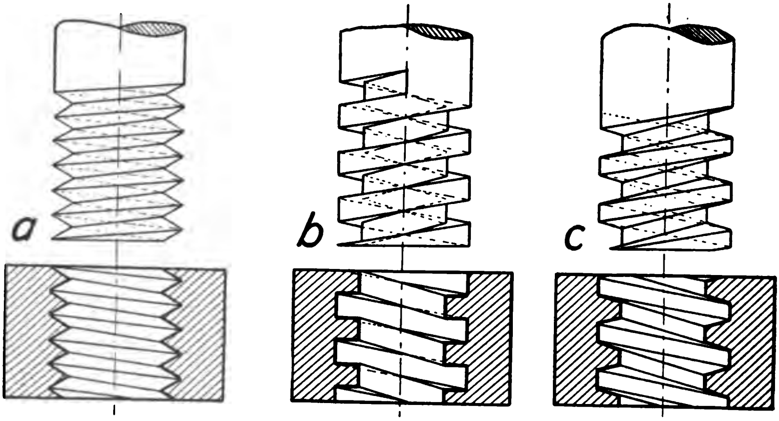


FIGURE 98.

The Sharp V, Square and Acme threads are represented in Figure 98 by conventional drawings in which straight lines are used instead of the more elaborate curved lines shown in Figure 1 of Plate XXXIV. These drawings all represent right-hand threads although the section through the nut apparently represents a left-hand thread. The reason for this is that only those lines of the thread are visible which are at the furthest side of the hole. If the drawing paper were transparent and the drawing of the screw should be placed over that of the nut, the lines of the hidden part of the thread of the screw would fit into those shown in the section of the nut.

In Figure 99, *a*, *b*, *c*, are methods of representing tapped holes, when hidden from view and which must be shown by dotted lines. *a* and *b* are commonly used, although *c* is sometimes preferred because of its simplicity. Top views of surfaces having tapped holes may be indicated either as at *d* or *e*. If as at *e*, a circle should be drawn of a diameter equal to the outside diameter of the bolt, and the

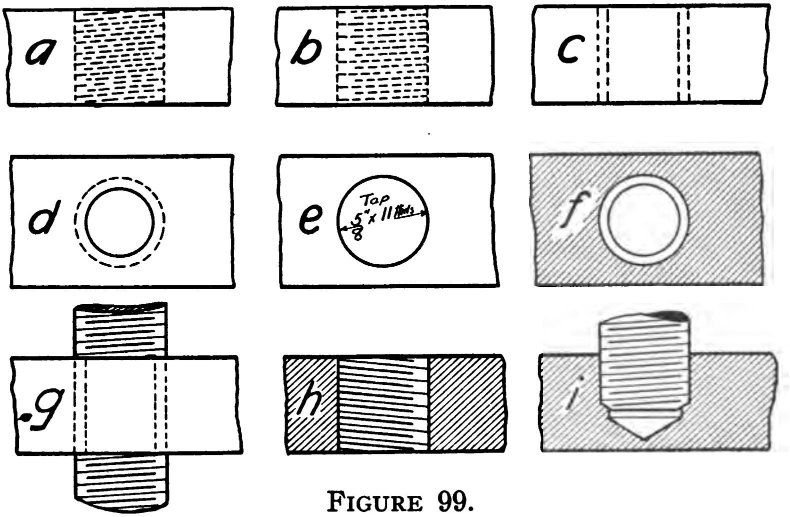


FIGURE 99.

circle dimensioned, thus stating that the hole is to be tapped and the size of bolt, kind and pitch of thread to be used. If the method at *d* is employed the inner circle should be approximately equal in diameter to the root diameter of the bolt and the outer dotted circle should equal the outside diameter of the bolt. At *f* is the top view of a tapped hole, as represented in a sectional view. At *g* is a representation of a threaded piece which extends through a block threaded to receive it, as shown. At *h* is a vertical section through a tapped hole. This is for a right-hand thread, although the lines represent a left-hand thread, for only that part of the thread is visible which is at the furthest side of the hole, where the threads incline in a direction opposite to the direction that they would take at the front side of the hole. This can be clearly seen by examining a bolt or nut. At *i* is a section through a tapped hole, with the screw in place, but not cut to show section.

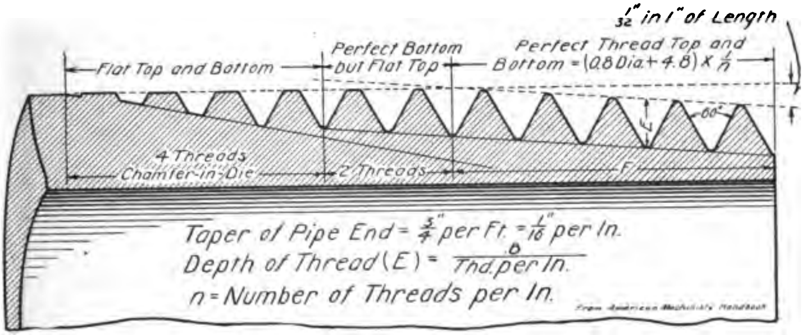
SCREW THREAD FORMULÆ.

For the United States Standard Thread.

d = nominal diameter of bolt
p = pitch of thread = $0.24\sqrt{(d+0.625)}-0.175$
n = number of threads per inch = $1'' \div p$
x = depth of thread = $0.75 \times p\ (\text{sine } 60^\circ) = 0.65p$
x' = total depth of V = $p\ (\text{sine } 60^\circ) = 0.866p$
e = effective diameter of bolt = $d-2x$
t = thickness of nut = *diameter of bolt*
h = thickness of bolt head = $0.75 \times d + 0.0625''$
f = distance between parallel sides of head or nut = $1.5d + 0.125''$
f^1 = distance across corners of hexagonal head or nut = $1.155f$
f^2 = distance across corners of square head or nut = $\sqrt{2f^2}$

THREADS PER INCH. U. S. STANDARD.

Diameter	$\frac{1}{4}''$	$\frac{5}{16}''$	$\frac{3}{8}''$	$\frac{7}{16}''$	$\frac{1}{2}''$	$\frac{5}{8}''$	$\frac{3}{4}''$	$\frac{7}{8}''$	$1''$	$1\frac{1}{8}''$	$1\frac{1}{4}''$	$1\frac{1}{2}''$
No. Threads	20	18	16	14	13	11	10	9	8	7	7	6


$\frac{1}{32}''$ in 1'' of Length
Flat Top and Bottom
Perfect Bottom but Flat Top
Perfect Thread Top and Bottom = $(0.8\,\text{Dia.} + 4.8) \times \frac{1}{n}$
60°
E
F
4 Threads Chamfer-in-Die
2 Threads
Taper of Pipe End = $\frac{3}{4}''$ per Ft. = $\frac{1}{16}''$ per In.
Depth of Thread (E) = $\frac{.8}{\text{Thd. per In.}}$
n = Number of Threads per In.

From American Machinist's Handbook

FIGURE 100.

Pipe Threads. The thread used on pipes is like the V thread in having an included angle of 60° but it has the top and bottom of the thread slightly rounded, so that the depth of cut or height of thread is equal to only four-fifths of the pitch, or equal to $0.8\frac{1}{n}$, if n be the number of threads per inch. Figure 100 illustrates a section of a Briggs Standard Pipe Thread, in which the proportions of the thread are indicated.

PITCH OF PIPE THREADS PER INCH.—BRIGGS STANDARD.

Nominal diameter inside of pipe	$\frac{1}{8}''$,	$\frac{1}{4}''$,	$\frac{3}{8}''$,	$\frac{1}{2}''$,	$\frac{3}{4}''$,	1'' to 2'',	2'' up
Number of threads	27,	18,	18,	14,	14,	$11\frac{1}{2}$	8

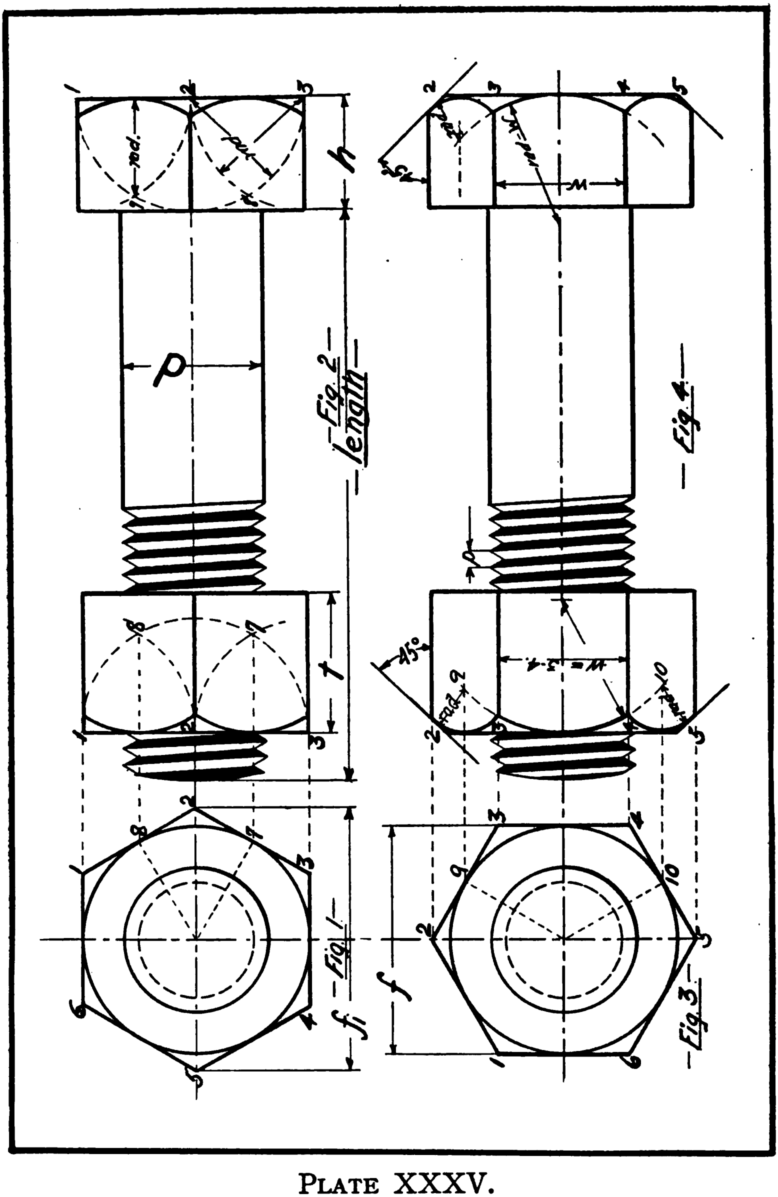


PLATE XXXV.

Bolt Heads and Nuts. The conventional method for representing hexagonal heads of bolts and nuts is shown in Plate XXXV.

In making a drawing for a standard bolt;

First make calculations (using the Screw Thread Formulæ) for parts *f*, *t*, *h*, and *p*, when *d=dia. of bolt.*

In Figure 2, with center at *2*, and rad. *2-1*, draw arc *1-3*; with centers at *1* and *3*, draw arcs *2-8* and *2-7*; with *7* and *8* as centers, draw lines tangent to line *1-3*.

In Figure 4, with center on the center line of bolt and rad. *3-4*, (*w*) draw an arc tangent to line *3-4*; bisect lines *2-3* and *4-5* in Figure 3 at *9* and *10*, and draw lines from these points obtaining *9* and *10* in Figure 4. With *9* and *10* as centers, draw arcs tangent to line *2-5*, and complete the chamfer by drawing lines at *45*°, tangent to these arcs.

In this representation the corners are chamfered at *45*° to the axis of the bolt and nut. For general machine construction the bolt with the hexagonal head and nut is preferred to the square head and nut, which is more often used in heavy construction or structural iron work. The square nut gives a better gripping surface for the wrench than the hexagonal nut, but the latter may be used in a more confined space, as it is only necessary to turn it through an angle of *60*° to get the wrench over the next two parallel faces, while the square nut has to be turned through an angle of *90*° under the same conditions.

Drawing Problems. *Determine pitch of threads by formula.*

84. Make drawings for a $1\frac{1}{2}''$ bolt, having hexagonal head and nut as illustrated in Plate XXXV. The length of the bolt under the head is 6″ and the thread is a Sharp V, cut a distance of $2\frac{3}{4}''$ from the end. Use convention for thread shown in Figure 98.

85. Make a working drawing for a planer bolt, $\frac{5}{8}''$ diameter, 4″ long under the head, having a $1\frac{1}{4}''$ square head, $\frac{3}{8}''$ thick. The nut to be a standard size hexagonal nut.

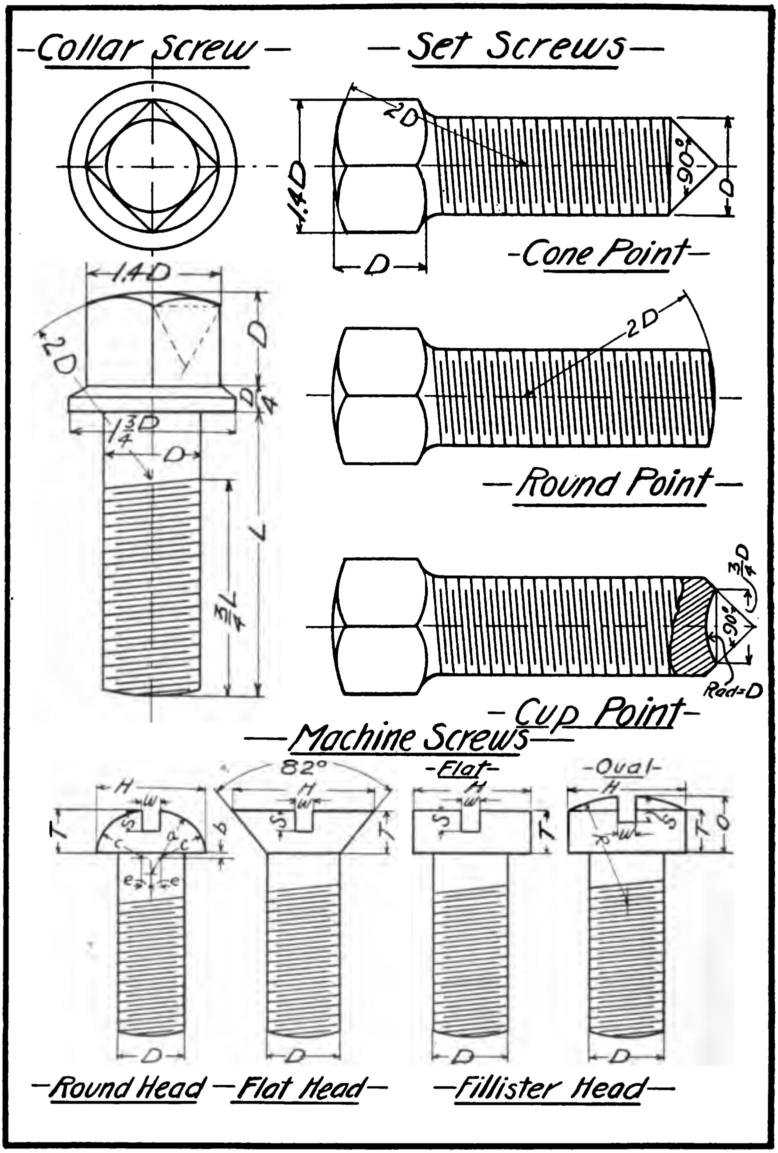

-Collar Screw-
—Set Screws—
2D
1.4D
90°
D
-Cone Point-
1.4D
2D
D
D/4
1 3/4 D
D
L
3/4 L
2D
—Round Point—
3/4 D
90°
Rad=D
-Cup Point-
—Machine Screws—
82°
-Flat-
-Oval-
H
W
S
T
a
c
e
b
O
D
—Round Head
—Flat Head—
—Fillister Head—

PLATE XXXVI.

Machine Cap Screws are made for fastening caps of bearings and covers on machines. Various styles of Machine or Cap Screws are shown in Plate XXXVI.

Collar Screws are used for the same purpose as cap screws. The collar giving a larger bearing surface for the head.

Set Screws are used to hold parts of machines in place by forcing the point of the screw against the part to be held in place. The various styles of set screws are known by the shape of the point of the screw.

PROPORTIONS OF MACHINE SCREWS.

D = Diameter of Body. H = Diameter of Head.
T = Thickness of Head. W = Width of Slot.
S = Depth of Slot.

Round Head	Flat Head	Flat Fillister	Oval Fillister
$H=1.83D$	$H=2D\ .0052$	$H=1.6D$	$H=1.6D$
$T=0.703D$	$T=\frac{D\ .0052}{1.739}$	$T=0.65D$	$T=0.65D$
$W=0.235D$		$W=0.235D$	$O=0.8D$
$S=0.40D$	$W=0.235D$	$S=0.325D$	$W=0.235D$
$a=1.095D$	$S=\frac{D\ .0052}{.5217}$		$S=0.4D$
$b=0.068D$			$R=2.186D$
$c=0.70D$			
$e=0.213D$			

Drawing Problems.

86. Make drawings for a collar screw, 1¼″ diameter and 3¼″ long under the collar, using the proportions given in Plate XXXVI.

87. Make drawings of each of the set screws illustrated in Plate XXXVI, the diameter of each screw being 1½″ and the length, 3¾″ under the head.

88. Make drawings of each of the machine screws illustrated in Plate XXXVI, the diameter of each being 1″ and the length 3″ under the head.

89. Pieces of round machine steel are to be used in making drawing room models illustrating the four different threads shown in Plate XXXIII. They are to be 10″ long and 2″ diameter, but having each end turned down $\frac{1}{8}''$ below the root diameter of the thread for $1\frac{1}{4}''$ from the end of the piece. Make a working drawing for one of these models and represent the conventional thread shown in Figure 98. The pitch of the thread is to be determined by the formula for number of threads per inch.

How many pounds of rough stock $2\frac{1}{8}''$ diameter must be ordered for the four models?

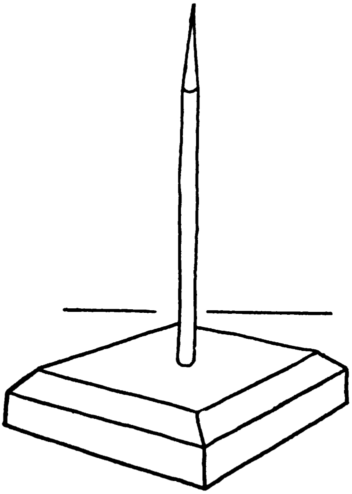


FIGURE 101.

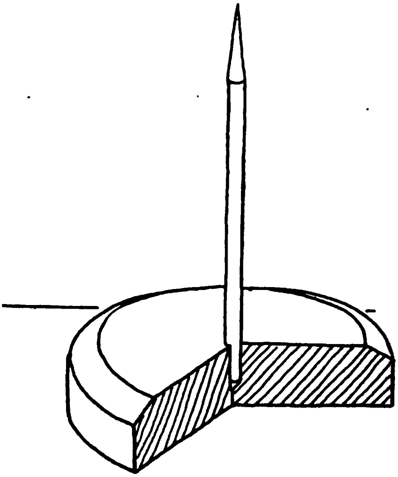


FIGURE 102.

WORKING DRAWINGS OF DETAILS

When drawing the following problems the pupil should make as many views as found necessary to adequately represent the object and fulfill the requirements stated in the specifications. In some instances two views will be enough but some of the problems will require a third view and perhaps a sectional view in order to make a complete working drawing which must also be fully dimensioned. As many of these drawings represent cast pieces, and are planned to be used in the patternmaking shop, the estimated weight of the rough casting should be given on the drawing. The problem states the kind of material to use in each case and this should be specified on the drawing.

90. **Paper File, Round Base,** Figure 102. Material cast brass. The lower base is $3\frac{1}{2}''$ diameter and the upper base is $2\frac{1}{4}''$ diameter. The thickness is $\frac{3}{4}''$, and the chamfer comes to a line $\frac{1}{2}''$ above the lower base. The spindle is made of brass wire, $\frac{5}{32}''$ diameter, $5''$ long, extending into the base $\frac{3}{8}''$, and ground down for the point $\frac{3}{4}''$ from the upper end.

91. **Paper File, Square Base,** Figure 101, has practically the same dimensions as the round base, except that the bases are $2\frac{1}{4}''$ and $3\frac{1}{2}''$ square instead of round.

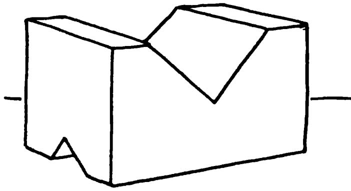


FIGURE 103.

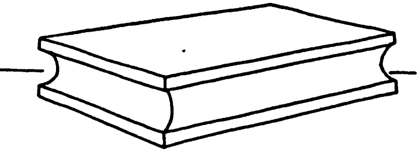


FIGURE 104.

92. **V Block,** Figure 103, is to be made of cast-iron and is to be $2''\times 3''\times 4''$ with grooves each having a 90° included angle. The grooves are $\frac{3}{4}''$ and $1\frac{1}{4}''$ deep. Finish all over.

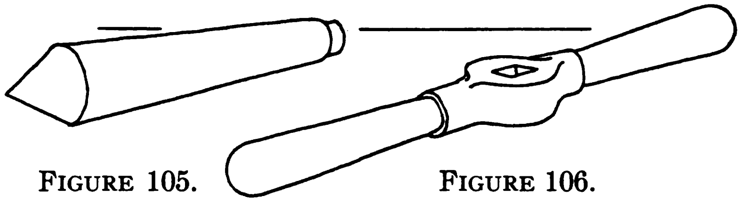


FIGURE 105. FIGURE 106.

93. Surface Plate or Bench Block, Figure 104, is to be made of cast-iron and is to be 4″×6″×1½″ with a groove which is a half-circle having a 7/16″ radius. Finish both bases.

94. Lathe Center, Figure 105, is to be made of tool steel, with length overall of 7″ and greatest diameter of 1¼″. The center end has an included angle of 60°, and the taper of hole in lathe spindle is ½″ per foot. The smallest end is turned straight for ¼″ to a diameter 3/16″ less than the diameter of the piece at that end after the taper is turned.

95. Tap Wrench, Figure 106, is to be made of machine steel. The overall length is 5½″: between the shoulders the length is 1½″, the center part is ¾″ across and ⅜″ thick, and the round part is ⅜″ diameter. The diameter of the handle at the large end is 7/16″ and at the shoulders it is 5/16″.

96. Cast Iron Washer, Figure 107. The largest diameter is 5″; hole diameter, 1¼″; thickness, 1⅛″ with a shoulder 1/16″ below upper base which is 2½″ diameter.

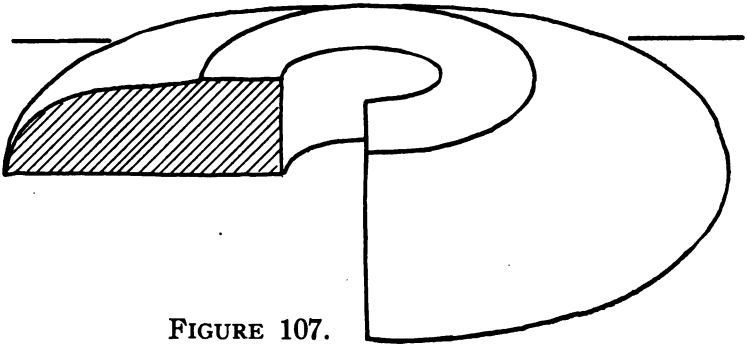


FIGURE 107.

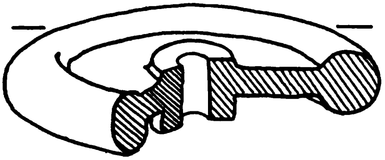


FIGURE 108.

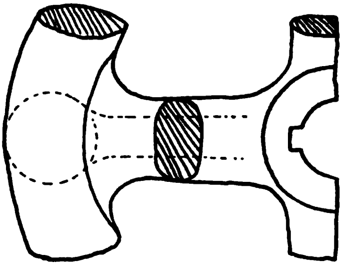


FIGURE 109.

97. Hand Wheel, Figure 108, is to be made of cast-iron. Its greatest diameter is 8″; diameter of rim is $1\frac{3}{16}''$; hub, $1\frac{1}{2}''$ diameter, projects $\frac{1}{2}''$ each side of web, which is $\frac{3}{8}''$ thick with fillets having $\frac{3}{8}''$ radius at hub and rim. Hand wheel is to be keyed to a $\frac{7}{8}''$ shaft.

Keys. In order to prevent pulleys, wheels, gears, etc., from turning on a shaft, rectangular pieces of steel are placed partly in the shaft and partly in the hub of the object on the shaft. These pieces are called keys; the grooves into which they fit are called keyways and usually run lengthwise of the shaft. *The proportions for Keys are*

When d=*diameter of shaft*

$$b = \textit{breadth of key} = \frac{d}{4}$$

$$t = \textit{thickness of key} = \frac{d}{6}$$

98. Hand Wheel, Figure 109. The drawing for this hand wheel must be made one-half full size and a section of the wheel indicates that this wheel has four arms. The diameter at the center of the rim is $12\frac{1}{2}''$ and a section through the rim is $1\frac{1}{2}''$ diameter. A section through the arm on a line tangent to the hub is $1\frac{3}{4}''\times\frac{3}{4}''$ and a parallel section at a point $3\frac{3}{4}''$ from the hub is $1\frac{3}{8}''\times\frac{5}{8}''$. Fillets are all $\frac{1}{2}''$ radius. Hub is $2\frac{1}{4}''$ diameter and measures $\frac{3}{4}''$ on one side and $1\frac{3}{4}''$ on the opposite side of a center-line drawn through arm and rim. The wheel is keyed on a shaft which is $1\frac{1}{4}''$ diameter.

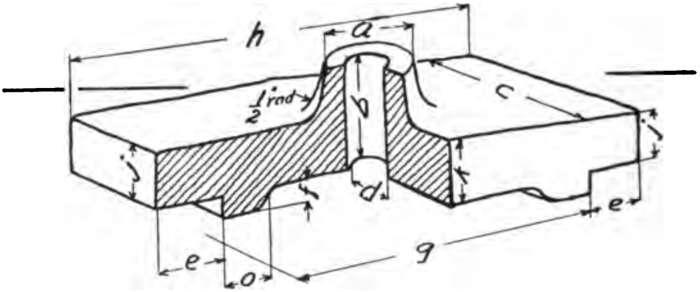


FIGURE 110.

99. **Clamping Plate,** Figure 110, is to be made of cast-iron and its proportions are: $a=\frac{7}{8}''$; $b=1\frac{1}{8}''$; $c=2\frac{1}{4}''$; $d=\frac{15}{32}''$; $e=\frac{1}{2}''$; $f=\frac{1}{4}''$; $g=2\frac{3}{4}''$; $h=3\frac{3}{4}''$; $j=\frac{3}{8}''$; $k=\frac{1}{2}''$; $o=\frac{1}{2}''$; finish end of hub.

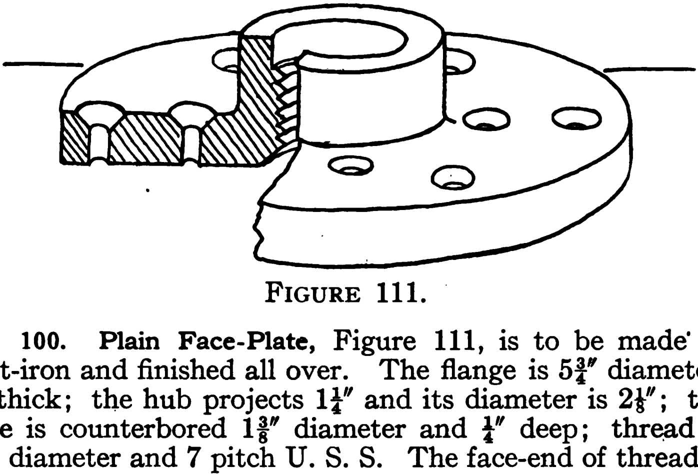


FIGURE 111.

100. **Plain Face-Plate,** Figure 111, is to be made of cast-iron and finished all over. The flange is $5\frac{3}{4}''$ diameter, $\frac{3}{8}''$ thick; the hub projects $1\frac{1}{4}''$ and its diameter is $2\frac{1}{8}''$; the hole is counterbored $1\frac{3}{8}''$ diameter and $\frac{1}{4}''$ deep; thread is $1\frac{3}{8}''$ diameter and 7 pitch U. S. S. The face-end of thread is chamfered at 45° to center-line; fillet in corner is $\frac{1}{4}''$ radius and the back corner of flange is rounded to a $\frac{1}{16}''$ radius. The screw holes are $\frac{1}{4}''$ diameter, countersunk to $\frac{17}{32}''$ diameter with 90° countersink. The center line circle of inner row of four holes is $3\frac{1}{8}''$ diameter, and of the outer row of six holes is $4\frac{7}{8}''$ diameter.

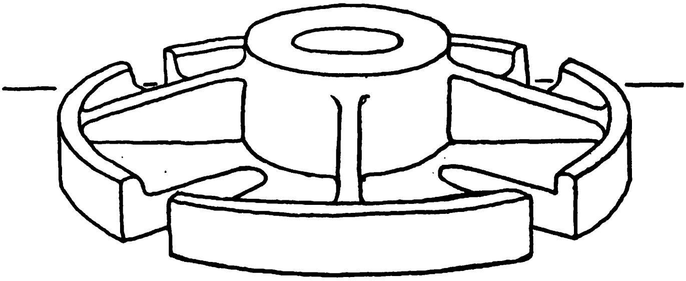


FIGURE 112.

101. **Ribbed Face-Plate,** Figure 112, is made of cast-iron. The greatest diameter is 6¼″; the hub is 2¼″ diameter, and 1 9/16″ long through the hole. The hole is counterbored on back end 1¼″ diameter, ¼″ deep; the thread is 1¼″ diameter and 8 pitch, U. S. S. The web is 7/16″ thick and the rim at the back is ¼″×¼″ thus making the outside of face-plate 11/16″ wide. The fillets in the corners are all ¼″ radius. The four slots are ⅝″ wide and extend to within ¼″ of the hub. The four ribs are 5/16″ thick, extending to within ¼″ of the end of the hub and 1/16″ below the edge of the rim. The face, outside diameter, and end of hub are to be finished.

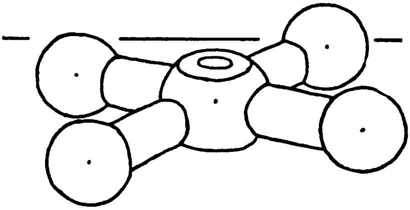


FIGURE 113.

102. **Hand Nut,** Figure 113. This is a clamping nut and the hub is a part of a 1⅛″ sphere, faced giving two faces ¾″ apart. The hole is tapped 7/16″ diameter, 14 pitch, U. S. S. thread. The outer spheres are ¾″ diameter and the overall dimension across the handle is 3¼″. The spokes are ½″ diameter. Material, cast-iron.

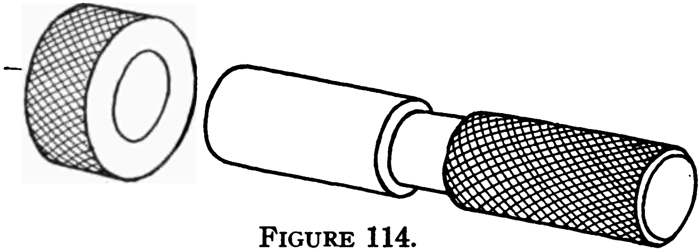


FIGURE 114.

103. Plug and Ring Gauges, Figure 114; three sizes required; material, tool steel, hardened, tempered and ground to size. Outside diameter of rings is $2\frac{1}{2}''$; thickness equal to diameter of hole in each. Total length of plug is $5\frac{3}{4}''$; handle is $3\frac{1}{4}''$ long and $\frac{1}{8}''$ less in diameter than gauge. The neck between handle and gauge is $\frac{1}{2}''$ long and $\frac{3}{8}''$ less in diameter than gauge. Indicate knurling by drawing lines in opposite directions, $\frac{1}{16}''$ apart at 30° to the center-line. Chamfer knurled end at 45°.

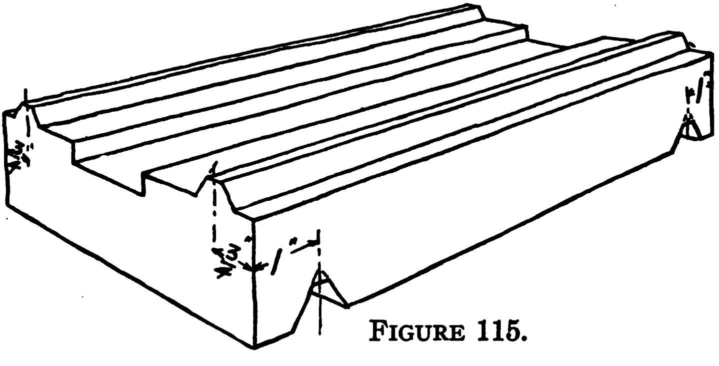


FIGURE 115.

104. Guide Block, Figure 115, is to be made of cast-iron and its overall dimensions are $2\frac{1}{2}'' \times 10'' \times 18''$. The height of the guides and the depth of the grooves are each $\frac{1}{2}''$, the greatest width of each being $\frac{3}{4}''$. The included angle of each is 60°. The rectangular groove in the top is $\frac{1}{2}'' \times 4\frac{1}{2}''$. This drawing should be made to a "*half size*" scale.

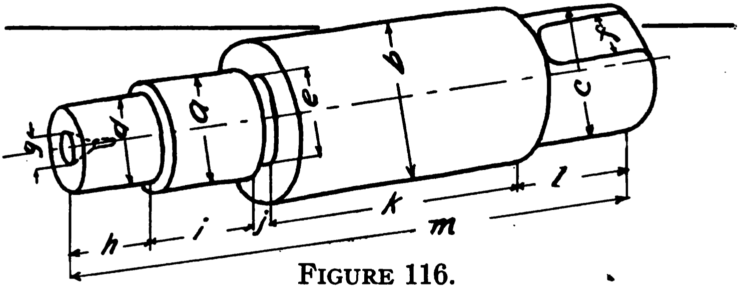


FIGURE 116.

105. Nut Arbors, Figure 116. These are made of steel and the proportions are given in inches in the following table. The part *a* is to have U. S. S. thread.

$j=\frac{1}{8}''$; $h=a$; $i+j=a$; $e=d$; $g=f$; $k=\ldots.$

a	b	c	d	f	l	m
$\frac{1}{2}$–13	$\frac{11}{16}$	$\frac{5}{8}$	.400	$\frac{9}{32}$	$\frac{11}{16}$	$3\frac{3}{4}$
$\frac{5}{8}$–11	$\frac{7}{8}$	$\frac{25}{32}$	.500	$\frac{11}{32}$	$\frac{7}{8}$	$4\frac{1}{4}$
$\frac{3}{4}$–10	1	$\frac{29}{32}$	.610	$\frac{3}{8}$	1	$4\frac{1}{4}$
$\frac{7}{8}$– 9	$1\frac{1}{8}$	1	.720	$\frac{13}{32}$	1	$4\frac{1}{2}$
1– 8	$1\frac{1}{4}$	$1\frac{1}{8}$	.825	$\frac{7}{16}$	$1\frac{1}{8}$	5

106. Collar Stud similar to collar screw shown in Plate XXXVI, but having a hexagonal head which measures $1\frac{1}{4}''$ across corners and from outside end of head to collar measures $\frac{21}{32}''$. The collar is $1\frac{7}{16}''$ diameter, $\frac{5}{32}''$ thick and chamfered with a round nose tool having a $\frac{1}{4}''$ radius, down to the corners on the head side. Under the head the body of the stud is $1''$ diameter for a length of $1\frac{9}{32}''$, the remaining length is turned down to $\frac{3}{4}''$ diameter and has a U. S. S. thread of the proper pitch. The overall length of the stud is $2\frac{15}{16}''$. Make neck at the shoulder, $\frac{1}{8}''$ wide, and $\frac{1}{64}''$ below depth of thread.

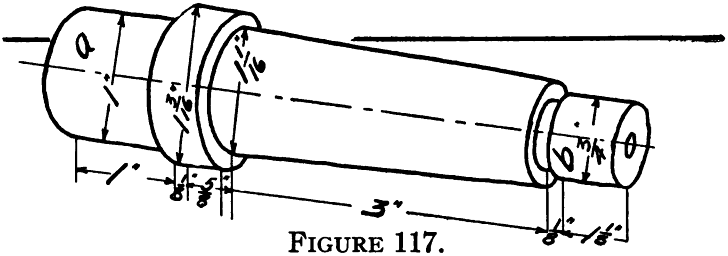


FIGURE 117.

107. **Taper Stud,** Figure 117, is threaded at *a* and *b* with U. S. S. threads of the proper pitch. The stud is necked down to the bottom of the threads at the shoulders. The taper is $\frac{1}{2}''$ to the foot. What is the diameter at the small end of the taper part?

The following table of weights of materials may be used in estimating the weights of castings, etc., called for in the problems.

Metal	Weight per Cubic Inch	Weight per Cubic Foot
Aluminum..........	.0924	159.66
Brass, cast..........	.3029	523.41
Bronze.............	.319	551.23
Copper.............	.322	556.41
Iron, cast...........	.2604	450.
Iron, wrought.......	.277	480.13
Lead...............	.41	709.4
Steel, cast..........	.28	481.2
Steel, rolled.........	.2833	489.6
Tin.................	.2634	455.08

WORKING DRAWINGS FOR SPUR GEAR WHEELS

NOTE:—The drawing problems in this course concerning spur gear blanks, do not require knowledge of the theory of gear teeth which treats of the proper formation and shape of the tooth curves in regard to action, strength and wearing qualities of certain forms of teeth. Discussion on that important problem may be found in NOTES FOR MECHANICAL DRAWING and it will also be treated more completely in a second book of this series which is now in preparation.

A Spur Gear Wheel is a toothed wheel with the teeth cut parallel with the axis of the wheel or cylinder. Spur gears are usually designated by the pitch of the teeth in the gear. For instance a gear may be called a *10 pitch, 32 tooth gear*, which means that the gear has 32 teeth cut in its cylindrical surface by a cutter known as a 10 pitch cutter. A cylinder or wheel intended for a gear is called a *gear blank* before the teeth are cut.

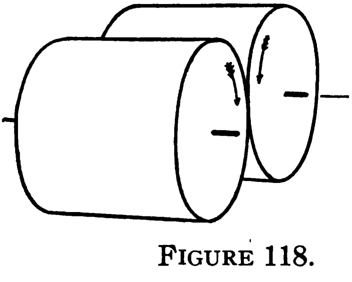


FIGURE 118.

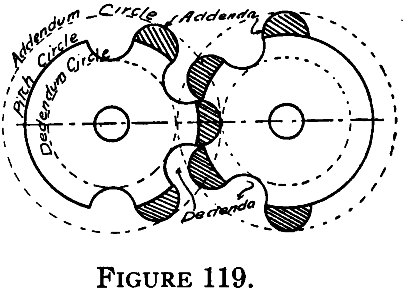


FIGURE 119.

Consider two cylinders having perfectly smooth lateral surfaces placed in such a position that each may revolve on its own axis, and with the lateral surfaces parallel and touching each other under pressure as in Figure 118. If one of these cylinders should be revolved about its axis, the friction between the two surfaces would cause the other cylinder to revolve in the opposite direction, but very little

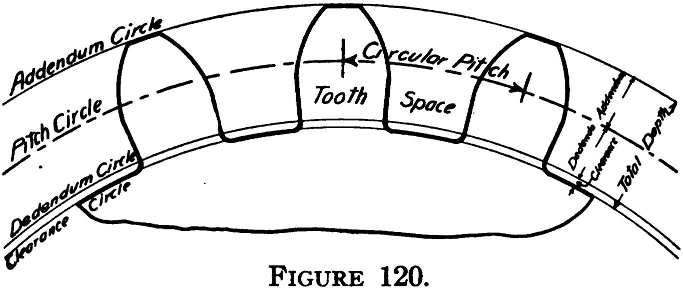


FIGURE 120.

power would be transmitted from the driving cylinder to the other because of the slipping between the two surfaces. If equally spaced grooves should be cut in the lateral surfaces of the cylinders and a certain amount added on to the parts between the grooves thus making teeth as illustrated in Figure 119 the *toothed cylinder* would then be called a *gear*. The original cylinder in which the grooves are cut and the parts added upon is called the *pitch cylinder*. The circle representing the circumference of the pitch cylinder is called the *pitch circle* of the gear wheel. *All calculations for the sizes of gear wheels and the shape of the gear tooth are based upon the size of the pitch circle and the number of teeth it contains.* That part of the pitch cylinder cut away by the grooves is called the *dedenda* (to take away from, to deduct). That part added to the pitch cylinder between the grooves is called the *addenda* (added to), which taken together with that part between the grooves upon which it is placed, is called the *tooth* of a gear. The diameter of the pitch circle plus the addenda on opposite sides of the gear makes the *outside diameter* of the gear. The dedenda is equal to the addenda and there is also allowed one-eighth of the addenda for *clearance* at the bottom of the groove. The total depth of cut or height of tooth is equal to the addenda, plus the dedenda, plus the clearance. (Figure 120.) The distance between the centers of the teeth measured on the pitch circle is called the *circular pitch*. If the gear has a certain number of teeth cut in the circumference of its pitch circle based on each inch of its pitch diameter, the pitch is called the *diametral pitch.* Should there be 10 teeth in the circumference for each inch of diameter of the pitch circle the gear would be called a *10 diametral pitch gear.* When the size of a gear wheel is determined by diametral pitch, both the addendum and the dedendum are each equal to one pitch—part of an inch, or 1″ divided by the diametral pitch.

In a 10 diametral pitch gear, the addendum and dedendum each are .10″ to which is added a clearance of one-eighth of the addendum which is .0125″ thus making the total depth of cut or the height of the tooth equal to the

addendum (.10″) +dedendum (.10″) +clearance (.0125″) = .2125″

When calculations are based on the *circular pitch* of a gear, the addendum and dedendum are each equal to one-third of the circular pitch.

The relation between the diametral pitch and the circular pitch is the same as that between the diameter and circumference of a circle, therefore the circular pitch of a 10 diametral pitch gear would be 1″÷10×3.1416=.31416″.

The thickness of tooth and the width of the space are equal when measured on the pitch circle.

Drawing Problem 108. Make a working drawing for a 10 diametral pitch, 32 tooth gear blank which is 1″ thick and having a hole diameter of 1$\frac{1}{4}$″. (Figure 121.)

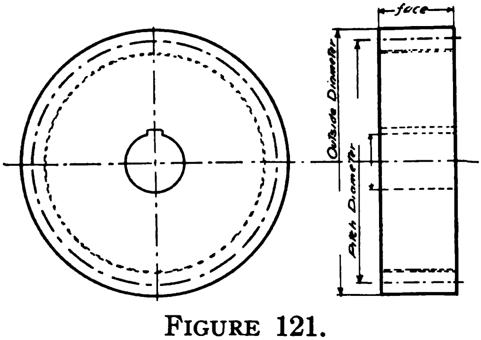


FIGURE 121.

To find the outside diameter of a gear when the number of teeth and pitch are given it is first necessary to determine the pitch diameter to which must then be added the addendum on each side of the pitch circle, as indicated in Figure 119. To determine the pitch diameter for a diametral pitch gear, multiply the number of teeth by one inch and divide by the diametral pitch. When the calculations are based on the circular pitch, the number of teeth must be multiplied by the circular pitch and this product divided by 3.1416. In diametral pitch, the number of teeth determines the number of pitch parts in the pitch diameter, and as two pitch parts must be added for the addenda, the outside diameter may be determined by the

Formula: $$\frac{\textit{no. of teeth} + 2\times 1''}{\textit{diametral pitch}} = \textit{outside diameter of gear}$$

for the problem the calculation would be

$$\frac{32+2\times 1}{10} = 3.4'' = \textit{outside diameter}$$

To find the pitch when the outside diameter and the number of teeth are given: add two to the number of teeth and divide the outside diameter by this number. If the outside diameter of a gear wheel is 8.25″ and the number of teeth is 64 then according to the

Formula: $$\frac{\textit{outside dia.}}{\textit{no. of teeth} + 2} = \textit{1 pitch part of } 1''$$

and $\frac{8.25''}{64+2} = .125''$: $1'' \div .125'' = 8$ *dia. pitch*

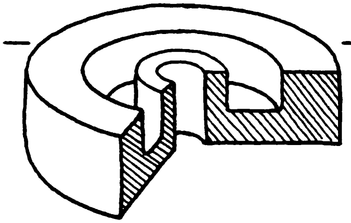


FIGURE 122.

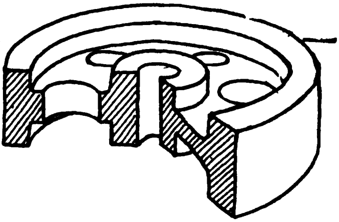


FIGURE 123.

109. **Gear Blank,** Figure 122, is to have 60 teeth, 10 diametral pitch. Face of gear is $1\frac{1}{4}''$ and rim is $\frac{5}{8}''$ thick. Hub is $1\frac{3}{4}''$ diameter at the web, $1\frac{1}{2}''$ at the outer end, and projects $\frac{7}{8}''$ from web which is $\frac{1}{2}''$ thick with fillets of $\frac{1}{4}''$ radius. Gear is to be keyed to $\frac{3}{4}''$ shaft.

110. **Gear Blank,** Figure 123, is to have 80 teeth, 12 diametral pitch. The web in this gear is to be at the center of the hub and rim and other dimensions are the same as in preceding problem with the exception of the rim which is to be $\frac{1}{2}''$ thick, and outside diameter of gear. The hub projects $\frac{3}{8}''$ each side of web. There are six $1\frac{1}{4}''$ holes through the web, located in the center of the space between hub and rim.

111. **A Spoked Gear Wheel** has 36 teeth and the depth of the cut between the teeth is $\frac{17}{32}''$. What diametral pitch cutter is to be used in cutting the teeth and what is the outside diameter of the gear wheel? This gear is to have six arms, or spokes, and a section of a spoke on a line tangent to the hub, is $1\frac{3}{4}''\times\frac{5}{8}''$. At a point $1\frac{1}{2}''$ from the outside circumference a section through the spoke is $1\frac{3}{8}''\times\frac{1}{2}''$. The hub is $3\frac{3}{4}''$ diameter and the gear is to be keyed to a shaft, $2''$ diameter. The face of the wheel is to be $1\frac{3}{4}''$ and the rim is $1\frac{1}{8}''$ thick. The hub is $2\frac{3}{4}''$ long measured through the hole, and all fillets are $\frac{1}{2}''$ radius. Make drawing to "*half size*" scale.

DECIMAL EQUIVALENTS

—: OF PARTS OF ONE INCH :—

1/64	.015625	33/64	.515625
1/32	.03125	17/32	.53125
3/64	.046875	35/64	.546875
1/16	.0625	9/16	.5625
5/64	.078125	37/64	.578125
3/32	.09375	19/32	.59375
7/64	.109375	39/64	.609375
1/8	.125	5/8	.625
9/64	.140625	41/64	.640625
5/32	.15625	21/32	.65625
11/64	.171875	43/64	.671875
3/16	.1875	11/16	.6875
13/64	.203125	45/64	.703125
7/32	.21875	23/32	.71875
15/64	.234375	47/64	.734375
1/4	.25	3/4	.75
17/64	.265625	49/64	.765625
9/32	.28125	25/32	.78125
19/64	.296875	51/64	.796875
5/16	.3125	13/16	.8125
21/64	.328125	53/64	.828125
11/32	.34375	27/32	.84375
23/64	.359375	55/64	.859375
3/8	.375	7/8	.875
25/64	.390625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	.421875	59/64	.921875
7/16	.4375	15/16	.9375
29/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375
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